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TNT EQUIVALENCY OF M1 PROPELLANT (BULK)

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DECEMBER 1975

PICATINNY ARSENAL
DOVER, NEW JERSEY

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TNT equivalency tests were performed with M1, single and multi-perforated, propellant. Peak pressure and positive impulse was measured as a function of distance from the charges. Configurations tested were sealed shipping drum containers and scaled open top and closed top feed hoppers. The TNT equivalency for these propellants was computed from the test blast output measurements. It was determined that the single-perforated (0.013 inch web) M1 propellant yielded a higher blast output in all configurations tested, than the multi-perforated (0.025 inch web) M1 propellant. The highest TNT

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equivalencies computed were at small sealed distances, * 3 ft/lb$^{1/3}$, for the sealed shipping drum configurations (M1-SP propellant). They were 240 and 170 percent for peak pressure and positive impulse respectively. In general, the measured blast output from the closed top feed hoppers was greater than that measured from the open top hoppers.

* cube root of 3 ft. lb.

FOREWORD

IIT Research Institute (IITRI) has conducted an experimental program to determine the TNT equivalency of two M1 propellant granulations. The work was conducted for the Manufacturing Technology Directorate, Picatinny Arsenal, Dover, New Jersey as a section of Contract DAAA21-73-C-0737. It is part of the overall program entitled "Safety Engineering in Support of Ammunition Plants."

The purpose of this report is to provide engineering data that can be used in facility siting and structure layouts developed in connection with the Army's Modernization and Expansion program for installations and activities.

Technical guidance was provided by Mr. L. Jablansky, P. Price, and D. Westover of the Manufacturing Technology Directorate, Picatinny Arsenal, Dover, New Jersey. The experiments were conducted at IITRI's explosive test facility in La Porte, Indiana. In addition to the authors, IITRI personnel who made contributions to this program are R. Joyce, D. Hrdina, J. Daley and H. Napadensky.

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INTRODUCTION

Background

Past methods used for the system design and siting of manufacturing facilities of explosive materials have been based solely on gross quantities of material handled. Present day technology, however, has shown that in order to produce cost effective and safe facilities, design criteria should be based upon the requirements of the explosive material involved. With the new approach, specific hazards can be eliminated or reduced if the unique nature and blast output of the material are known.

In line with the new interest and philosophy, modernization and redesign is currently being undertaken for equipment at various stages of the M1 propellant load and pack (LAP) operation and incremental net-weigh operation for ammunition charges using M1 propellant. Although all the equipment designs have not been finalized, it is known that bulk quantities of propellant will be well over 100 pounds at various stages of these operations. The largest concentrations of propellant occur in the feed hoppers associated with the weigh-scale and pack-out equipment. The hoppers planned at Indiana AAP, which are open on top, are to be used in bag loading operations. Those used at Radford AAP are in a closed system associated with the can (shipping drums) pack-out facility.

Considerable work has been performed in establishing air blast parameters of TNT. For facility designs involving other explosive materials, therefore, the required design information should be expressed in terms of "TNT Equivalency," i.e., the equivalent weight of TNT which will produce the same airblast environment as that produced by a quantity of detonable material involved.

Therefore, at the request of the U.S. Army Armament Command (ARMCOM), the Manufacturing Technology Directorate of Picatinny Arsenal has undertaken a study, in connection with its overall explosive safety program entitled "Safety Engineering in Support of Ammunition Plants," to determine the TNT equivalency of M1 propellant.

Objective

The objective of this work was to experimentally determine the maximum output from the detonation of two M1 propellant granulations (single-perforated, 0.013-inch web size, and multiperforated, 0.025-inch web size) in terms of their airblast overpressure and impulse. The measured pressure and impulse values are to be compared with those produced by a hemispherical surface burst of TNT in order to determine the TNT equivalency of the M1 propellant.

DESCRIPTION OF EXPERIMENTS

Test Site

A series of tests were conducted on M1 propellant at the IIT Research Institute (IITRI) explosives research laboratory near LaPorte, Indiana, under the technical supervision of the Manufacturing Technology Directorate of Picatinny Arsenal.

A schematic diagram of the test area physical arrangement is shown in Figure 1. It consists of two concrete slabs 75 feet long by 10 feet wide in which 12 pressure transducers were installed. The pressure transducers were mounted flush with the top surface of the concrete slab in mechanically isolated steel plates. The gauges were located at intervals on radial lines from ground zero (GZ). The gauge positions ranged from 8 to 80 feet from GZ.

Test Configurations

Three basic configurations were tested. The first simulation consisted of scaled cardboard drums which dimensionally represented the actual shipping drum containers. In the second configuration, the geometry included a truncated pyramid appropriately scaled to represent the typical open feedhopper. The last configuration was the closed feedhopper system. A combined cylinder-cone shape geometry was used to represent the closed feedhopper simulation.

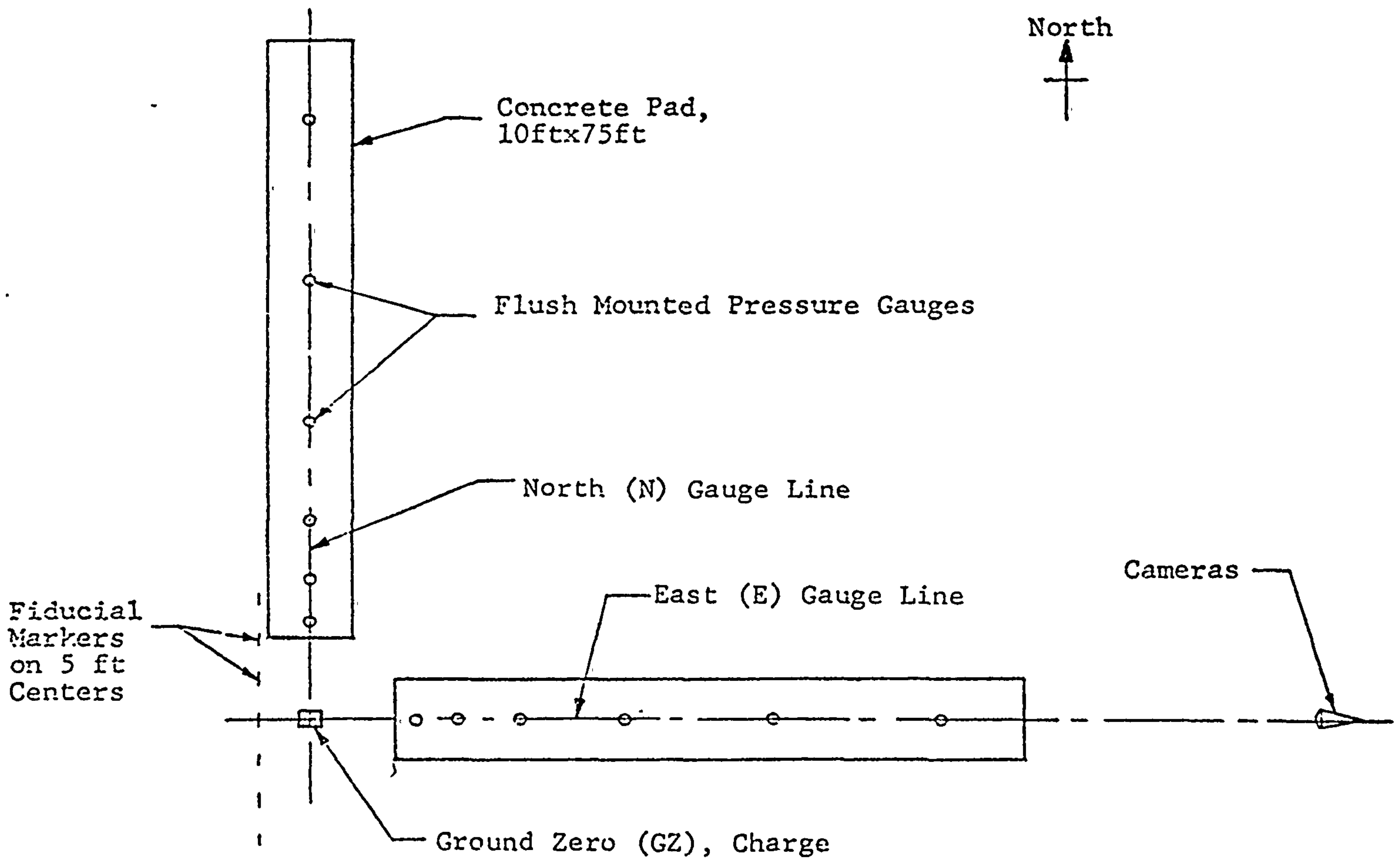


Fig 1 Test area

Two sizes of scaled shipping drums were used for the shipping container tests as follows:

Table 1

Scaled shipping container dimensions

Diameter (inches)	Height (inches)	Propellant weight (pounds)
11.00	19.00	43(SP) or 55(MP)
9.50	15.25	27(SP) or 35(MP)

Thus, the aspect ratio of the cylindrical drums was approximately the same as the aspect ratio of a full-scale cylindrical cardboard shipping drum (i.e., $L/D \sim 1.69$). Figure 2 illustrates the relative placement and spatial arrangement of the C4 explosive boosters with respect to the M1 propellant. These boosters were shaped to provide the aspect ratio of 1:1. A cardboard cap was placed over the cover so that the blasting cap could be inserted into the system.

The full-size hoppers to be used at Indiana and Radford Army Ammunition Plants are illustrated in Figure 3. Indiana AAP will be using two different size open hoppers for multiperforated (MP) and single-perforated (SP) M1 propellant. Normal operating loads are 130 pounds of SP and 190 pounds of MP in the open-feedhopper arrangement. The closed feedhopper system will be utilized at Radford AAP for both the SP and MP M1 propellant materials. Normal operating loads are 250 pounds for the SP material process and 303 pounds for the MP conditions.

Both Indiana and Radford hoppers were scaled down in size to accommodate the test site weight requirements. Scaling down the hoppers included preserving the ratios of the mass of M1 propellant/mass of hopper, and the aspect ratio of the hopper. The mass of the scaled hopper is changed by varying the thickness of the metal container, and the volume is changed by varying the physical dimensions of the hoppers, yet preserving their relative aspect ratios. Table 2 gives the dimensions of the scaled hoppers used during these tests. Materials used to construct the hoppers were 1/8-inch mild steel for

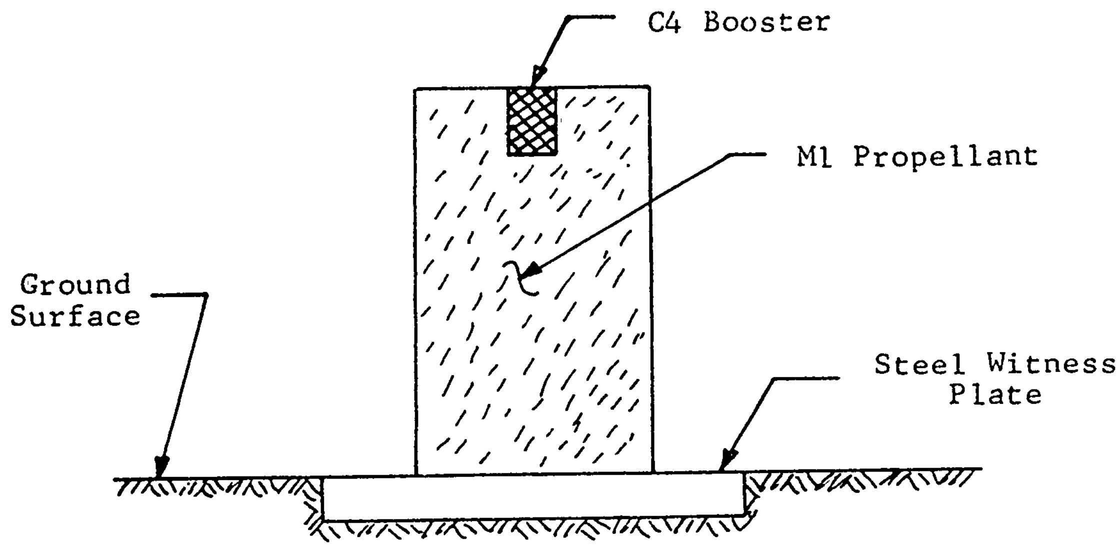


Fig 2 Cylindrical shipping drum configuration

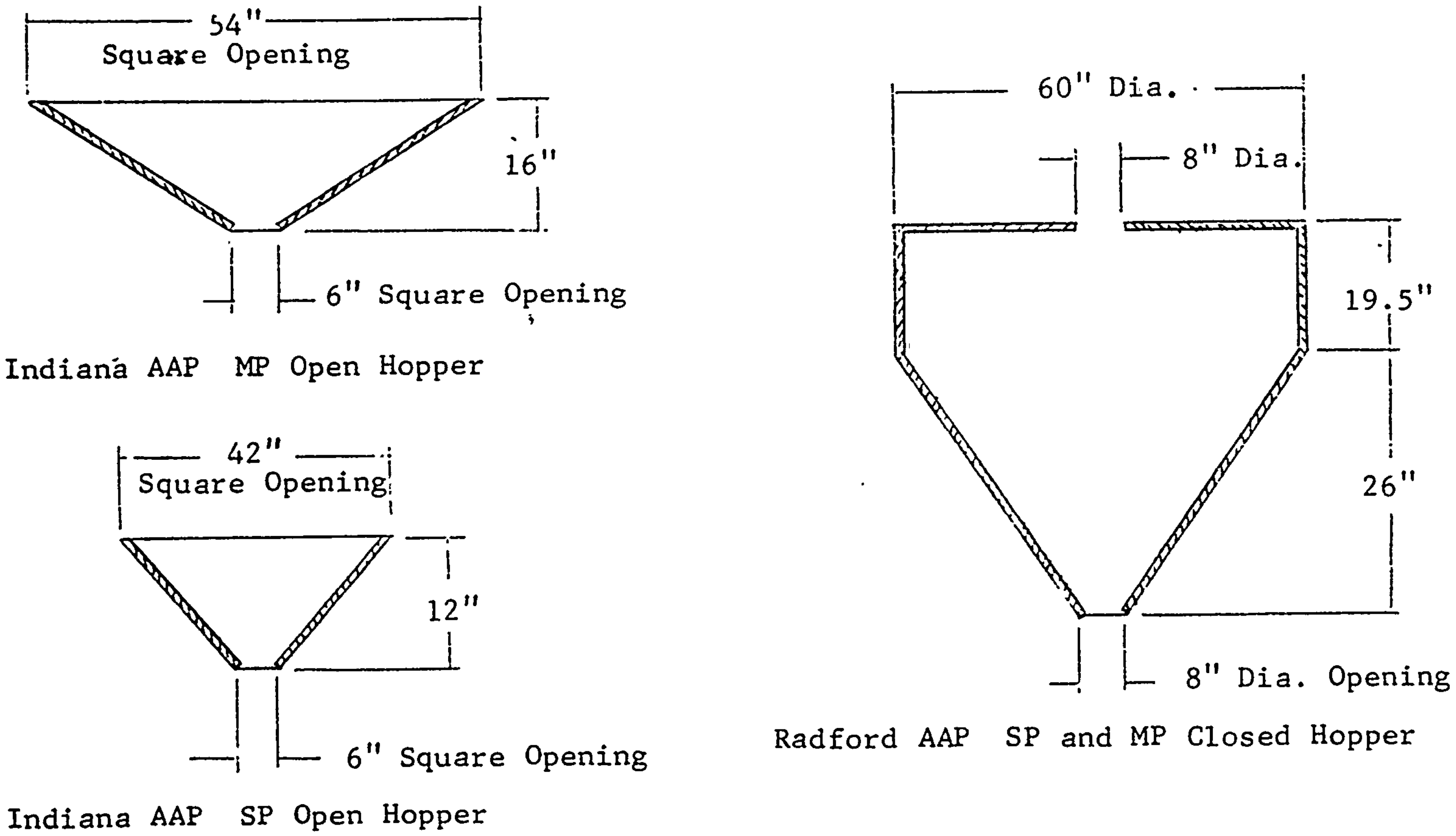
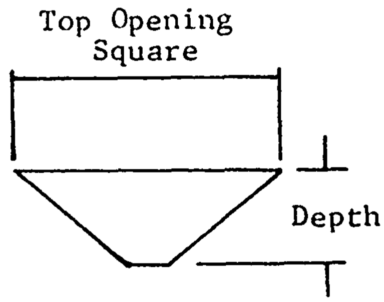


Fig 3 Full-size hopper configurations

Table 2

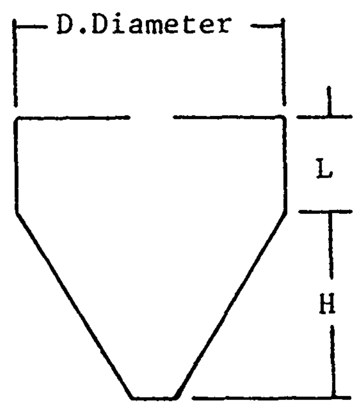
Scaled hopper dimensions

Nominal Load	Depth x Top Opening
Normal Load 130 lb SP	Full Scale Size 12 x 42 Square
50 lb SP	8.7 x 30.5 Square
Normal Load 190 lb MP	Full Scale Size 16 x 54 Square
50 lb MP	10.2 x 34.5 Square



Indiana AAP
Open Top Hopper

Nominal Load	D	L	H
Normal Load	Full Scale Size		
250 lb SP	60.0	19.5	26.0
50 lb SP	35.1	11.4	15.2
25 lb SP	27.9	9.1	12.1
12 lb SP	21.8	7.1	9.5
6 lb SP	17.3	5.6	7.5
Normal Load	Full Scale Size		
303 lbs MP	60.0	19.5	26.0
50 lbs MP	35.1	11.4	15.2



Radford AAP
Closed Top Hopper

the open hoppers and 5052-M32 aluminum for the closed hoppers, ranging in thickness from 1/8 inch to less than 1/10 inch, depending on the charge weight.

Charge weights in the open hoppers were 50 pounds for both propellant granulations. In the closed hoppers, 6, 12, 25 and 50 pounds of SP were tested; however, only 50 pounds of MP was tested.

The hoppers were positioned upright on the ground (at ground zero) over a steel witness plate. The propellant was poured into the hoppers and allowed to mound. Cylindrical C4 explosive boosters, with 1:1 aspect ratios, were buried in the propellant near the top of the mound.

Calibration Tests

During the course of this test program, several calibration tests were performed to confirm the recording accuracy of the pressure and impulse measuring systems. The calibration tests consisted of measuring the peak pressure and positive impulse from the detonation of a 5-pound hemispherical block of C4 explosive. The charge was set on a steel witness plate at ground level. Pressure and impulse data obtained from the C4 calibration shots was compared to established TNT hemispherical surface burst data. (The increased energetics of C4 are accounted for.)

TEST RESULTS

M1 Single-Perforated Propellant Tests

Shipping Drum Configurations

The tests performed in simulated shipping drum containers are summarized in Table 3. The tests are grouped according to nominal charge weights. Two charge weights were tested, 43 and 27 pounds. The results of these tests are plotted on Figure 4. The graphical representation of the data is extremely concentrated such that any visible distinction in peak pressure and positive impulse between the two different charge weights is not possible. Single curves for peak pressure and impulse were fitted to the data.

Analysis of the curves (Fig 4) for peak pressure and impulse as a function of scaled distance indicates that for the two charge weights an asymptotic approach to the maximum output level has been attained. Therefore, because of the data agreement, it can be generalized that an equivalent response for the full size shipping container weight (105 lb) can be expected.

The scaled distance and scaled impulse values presented in this report are based on the total charge weight. That is, the weight of the booster, in equivalent pounds of propellant, has been added to the propellant weight.

Open-Hopper Configuration

The three open-hopper (Indiana AAP hopper design) tests are listed in Table 3 for single-perforated M1 propellant. In each test, 50 pounds of propellant material was used and 2.5 pounds of C4 explosive boosters were used for ignition. The peak pressure and impulse relationships, as a function of scaled distance, are illustrated in Figure 5. At small scaled distances, 4 ft/lb$^{1/3}$, two curves are shown. Although the hoppers were symmetrical with respect to each gage line, different peak pressures and impulses were recorded along the two gage lines for the same test. These results indicate that the detonation phenomena in the configuration was not symmetrical. Secondly, the pressure-time wave shapes were multipeaked. The peak pressures recorded in Figure 5 are the maximums and are not necessarily the first peak. This would also explain the scatter in the data. The highest pressure and scaled impulse values will be used to compute TNT equivalency. Note that at scaled distances of less than approximately 8 ft/lb$^{1/3}$ the peak pressures and scaled positive impulses are substantially lower than those obtained from the shipping drum configuration tests.

Closed-Hopper Configuration

The closed-hopper configuration tests (Radford AAP hopper design) included charge weights of 6, 12, 25, and 50 pounds. The size of each hopper reflected the difference in the respective charge weights such that the corresponding aspect ratios were maintained at a constant magnitude. The characteristic pressure and impulse versus scaled distance relationships are illustrated in Figures 6, 7, and 8. At small scaled distances the configurations produced considerable scatter in the data, indicating nonuniform or unsymmetrical explosion phenomena. In addition, the pressure-time waves

Table 3

M1 single-perforated propellant tests

Test No.	Propellant Weight (W_P) (lbs)	Booster Weight (W_B) (lbs)	W_B/W_P (percent)	Field Observation
	Shipping Drum Configuration			
M1/AP-1R	43	1.5	3.5	Complete Ignition
M1/SP-2R	43	1.5	3.5	Complete Ignition
M1/SP-3R	27	0.88	3.3	Complete Ignition
M1/SP-4R	27	0.88	3.3	Complete Ignition
	Open Hopper Configuration (AAP)			
M1/SP-OH1	50	2.5	5.0	Complete Ignition
M1/SP-OH2	50	2.5	5.0	Incomplete Ignition
M1/SP-OH3	50	2.5	5.0	Incomplete Ignition
	Closed Hopper Configuration (RAAP)			
M1/SP-CH1	50	2.5	5.0	Incomplete Ignition
M1/SP-CH2	50	2.5	5.0	Incomplete Ignition
M1/SP-CH3	50	2.5	5.0	Incomplete Ignition
M1/SP-CH4	50	2.5	5.0	Incomplete Ignition
M1/SP-CH5	25	1.3	5.2	Complete Ignition
M1/SP-CH6	25	1.3	5.2	Complete Ignition
M1/SP-CH7	25	1.3	5.2	Complete Ignition
M1/SP-CH8	25	1.3	5.2	Complete Ignition
M1/SP-CH9	12	0.6	5.0	Complete Ignition
M1/SP-CH10	6	0.3	5.0	Complete Ignition

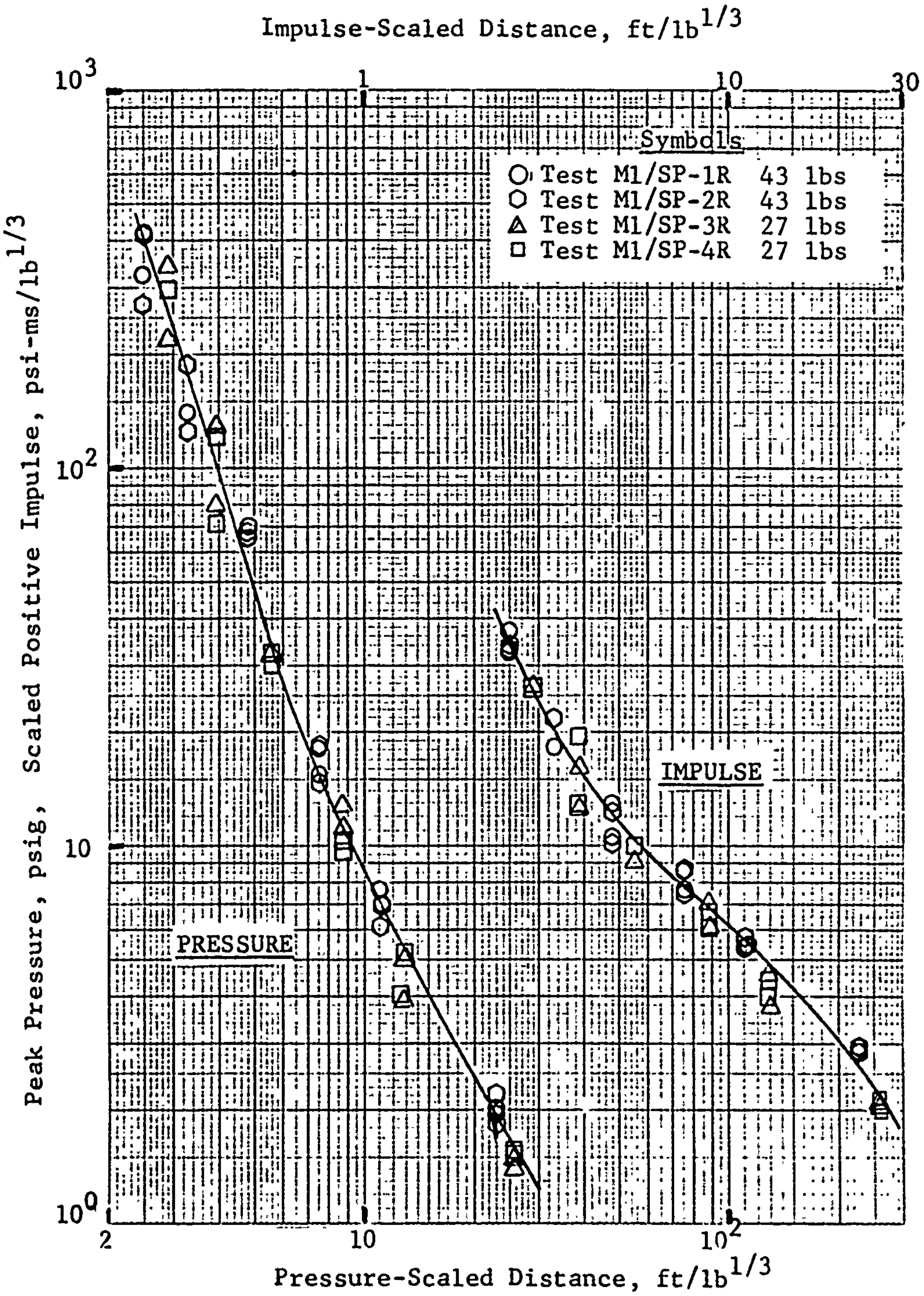


Fig 4 M1-SP shipping drum configuration

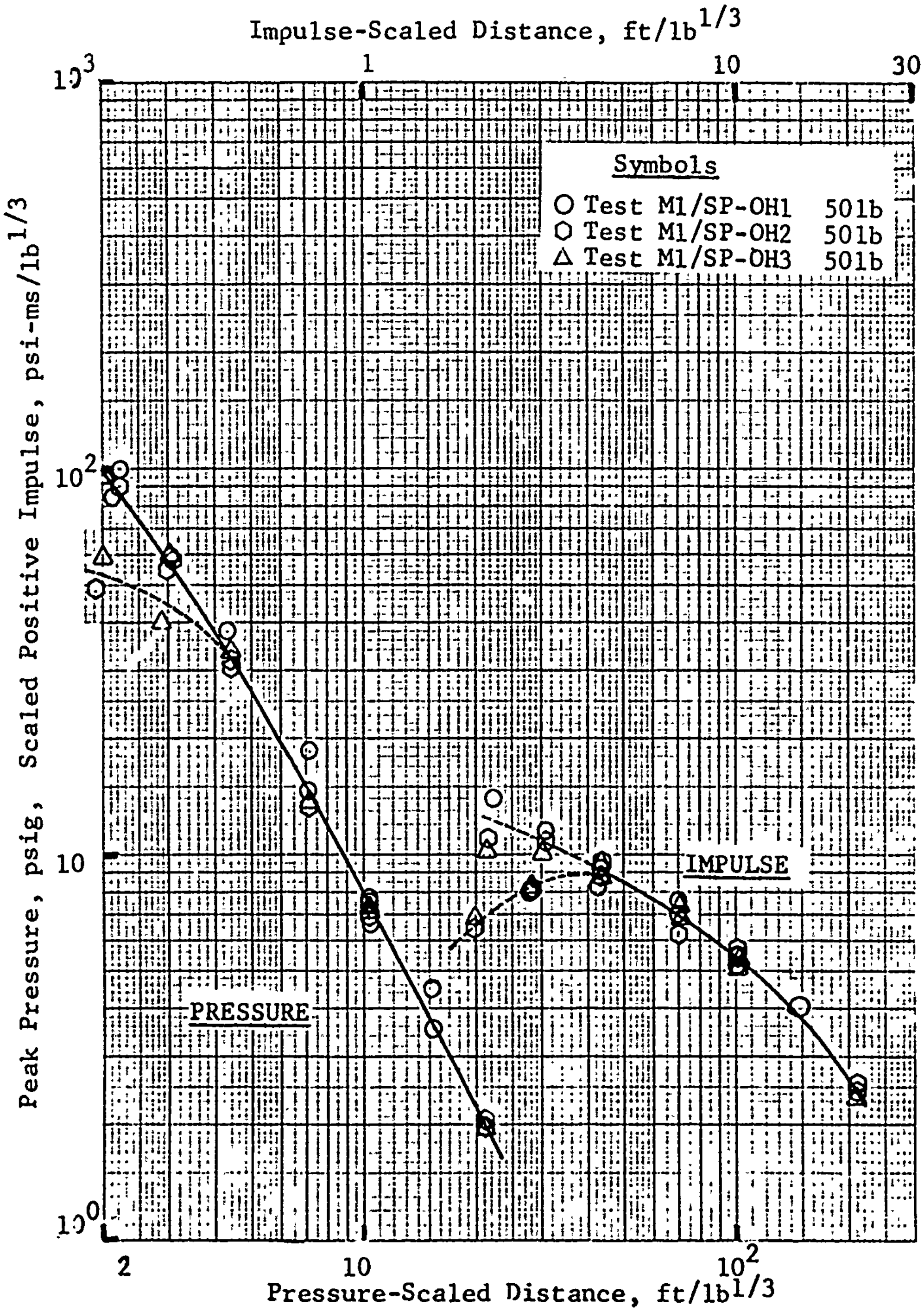


Fig 5 M1-SP open-hopper configuration

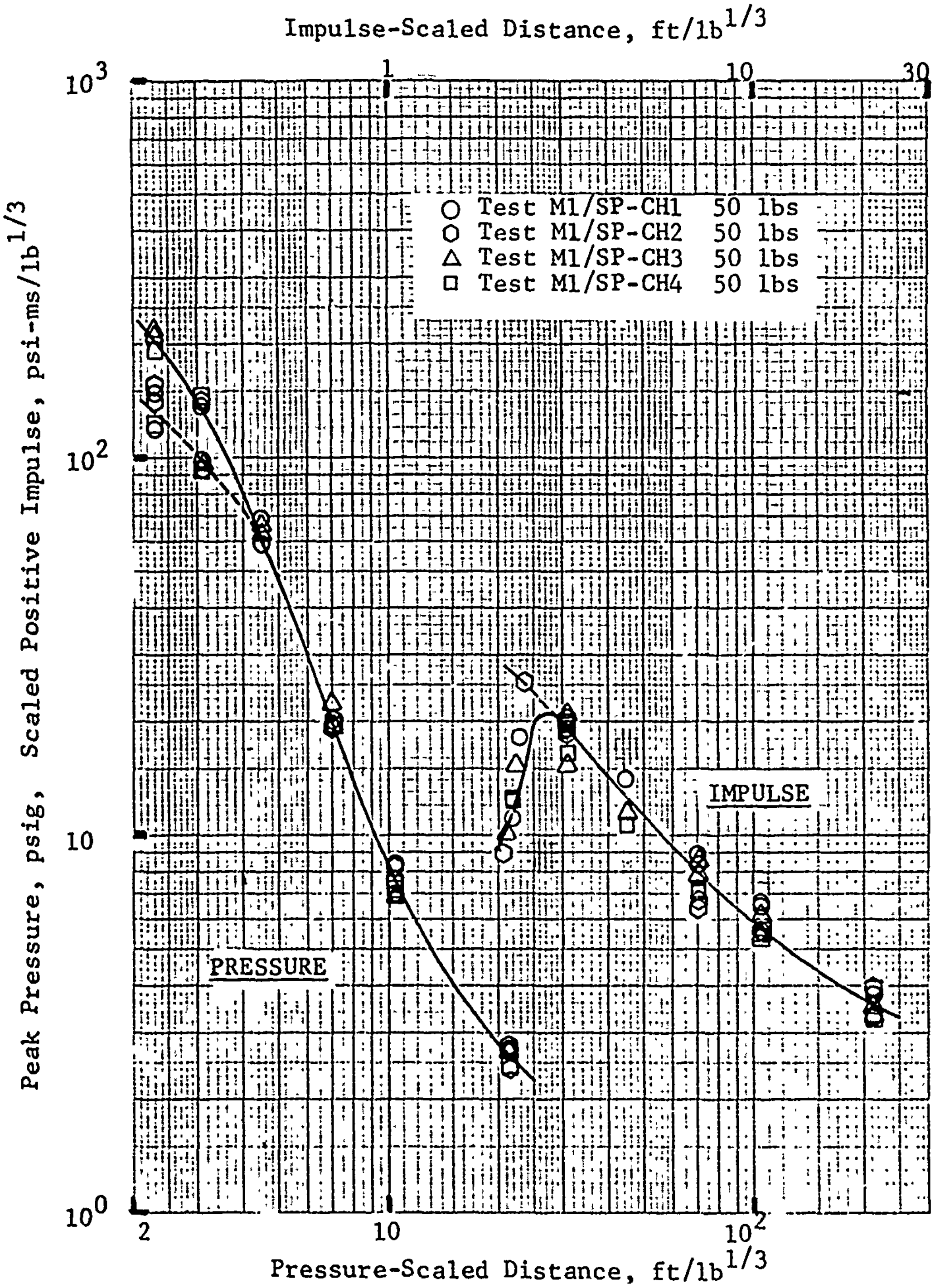


Fig 6 M1-SP closed-hopper configuration, 50 lb

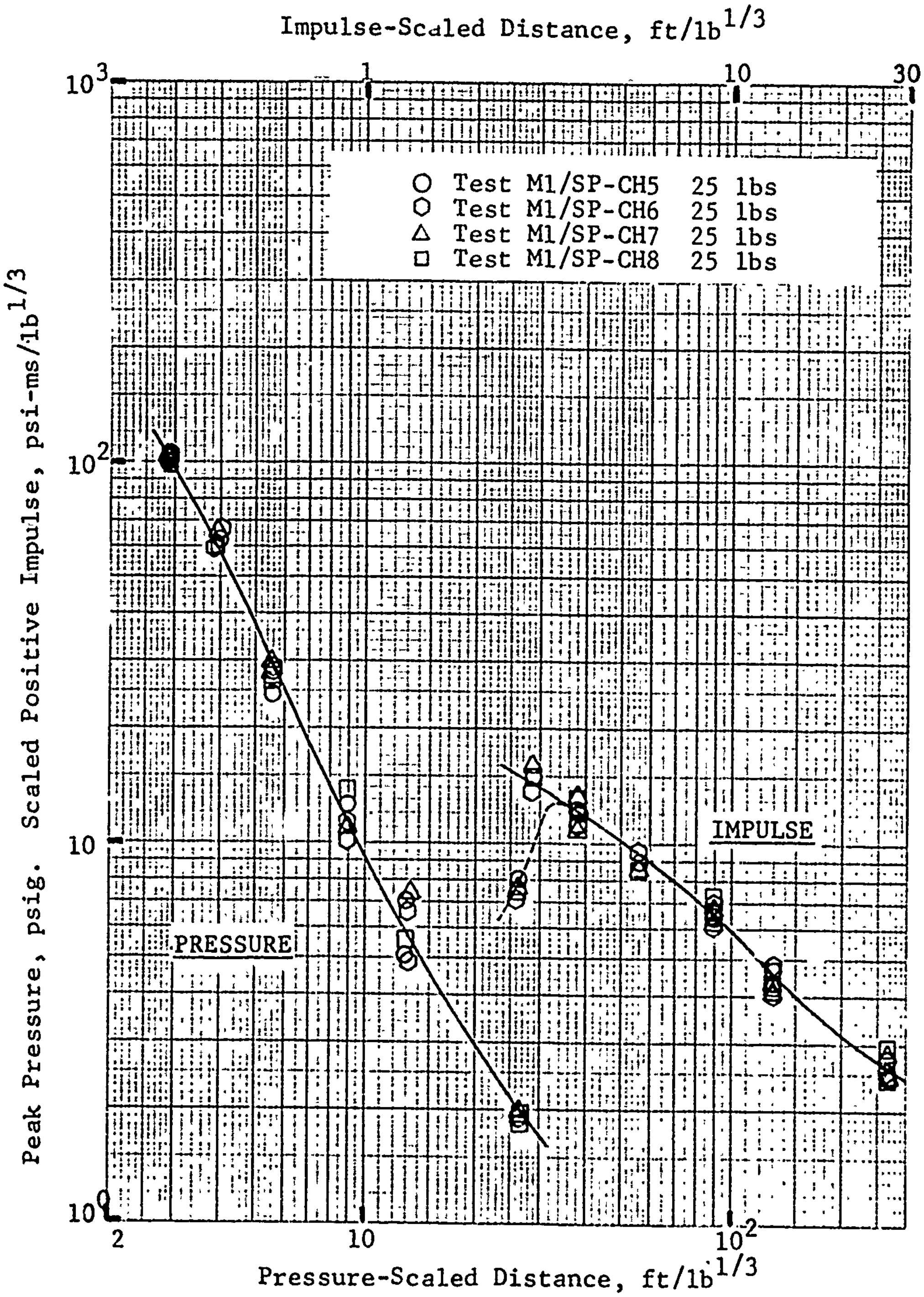


Fig 7 M1-SP closed-hopper configuration, 25 lb

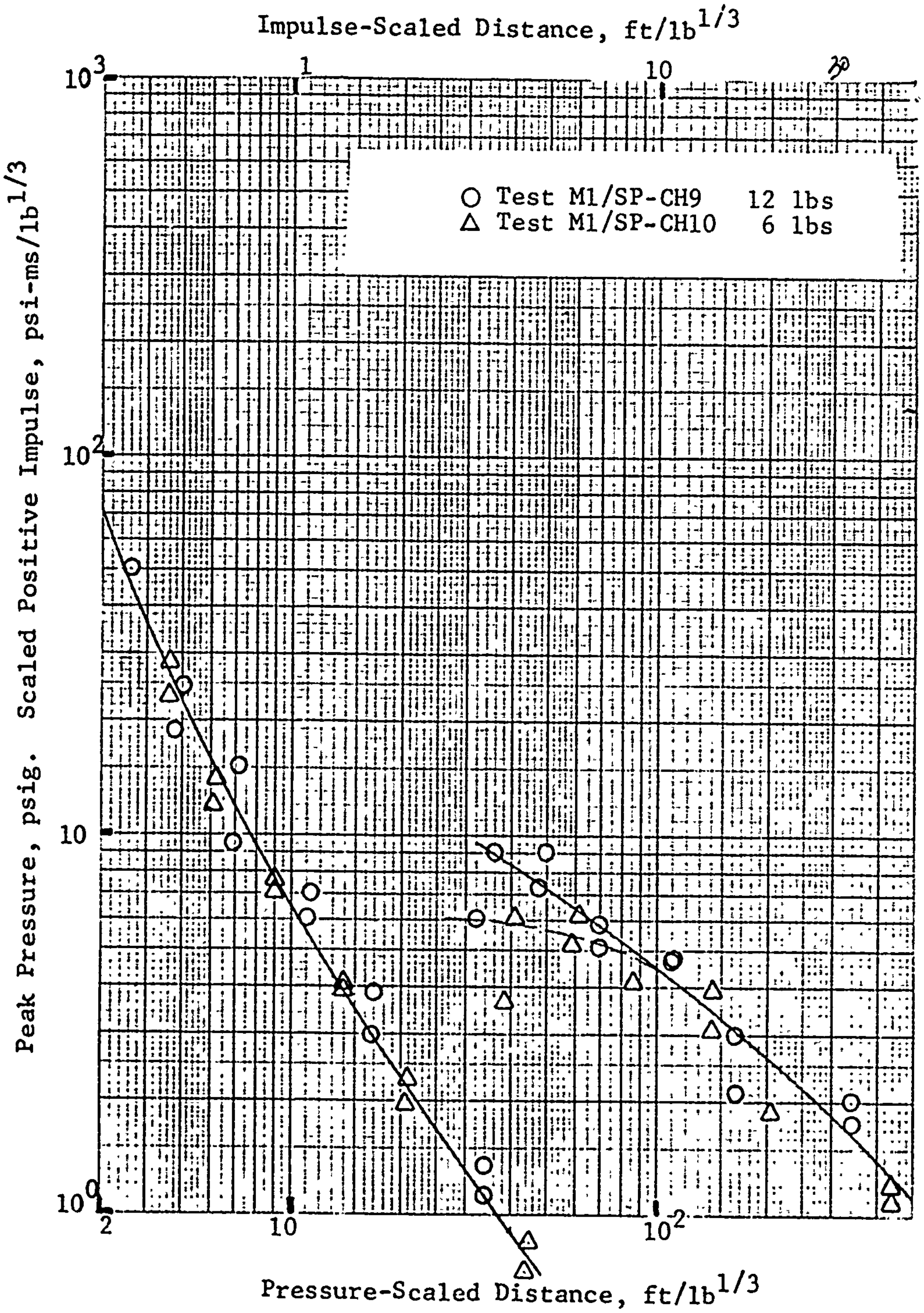


Fig 8 M1-SP closed-hopper configuration, 6 and 12 lb

were multi-peaked, similar to the open hopper test results. The maximum values of peak pressure and impulse are used to compute TNT equivalency.

Figure 9 illustrates the peak pressure and impulse variation as a function of charge weight for a number of scaled distances (λ = 3, 9, 18). For small magnitudes of charge weight (6 and 12 lb), the respective pressure-impulse characteristic curves are practically equivalent. Figure 8 represents the scaled blast outputs for the two different weights as a function of scaled distance. A minimal distinction in the blast output records is observed. In contrast, increases in scaled blast output versus scaled distance were observed for the 25- and 50-pound charges (Fig 6 and 7). With increasing scaled distances, both peak pressure and scaled impulse are observed to level off for increases of charge weight (Fig 9). A contrasting trend is also illustrated for small scalar distances. That is, the blast output record (pressure and scaled impulse) appears to continuously increase as the charge weight is increased, and an asymptotic limit is not apparent.

In summary, for the SP-M1 type propellant, the closed configuration yielded larger blast outputs in comparison to the open-hopper configuration.

M1 Multiperforated Propellant Tests

Shipping Drum Configuration

The tests conducted with M1 multiperforated propellant are presented in Table 4. The first series of tests were performed with sealed shipping drum containers for charge weights of 35 and 55 pounds. The results of these tests are illustrated in Figure 10. The larger drums and corresponding weight charges yielded greater blast outputs at all scaled distances. One can only conclude that for full-size shipping drums of multiperforated M1 propellant, an equal or greater scaled blast output than that for the 55-pound charge would be observed. For similar configurations and charge weights, a noteworthy observation is that the blast outputs of the SP-M1 and MP-M1 propellant types are substantially different for equal magnitudes of scaled distance. The performance of the multiperforated propellant is substantially lower than that of the single-perforated type (Fig 4 vs Fig 10).

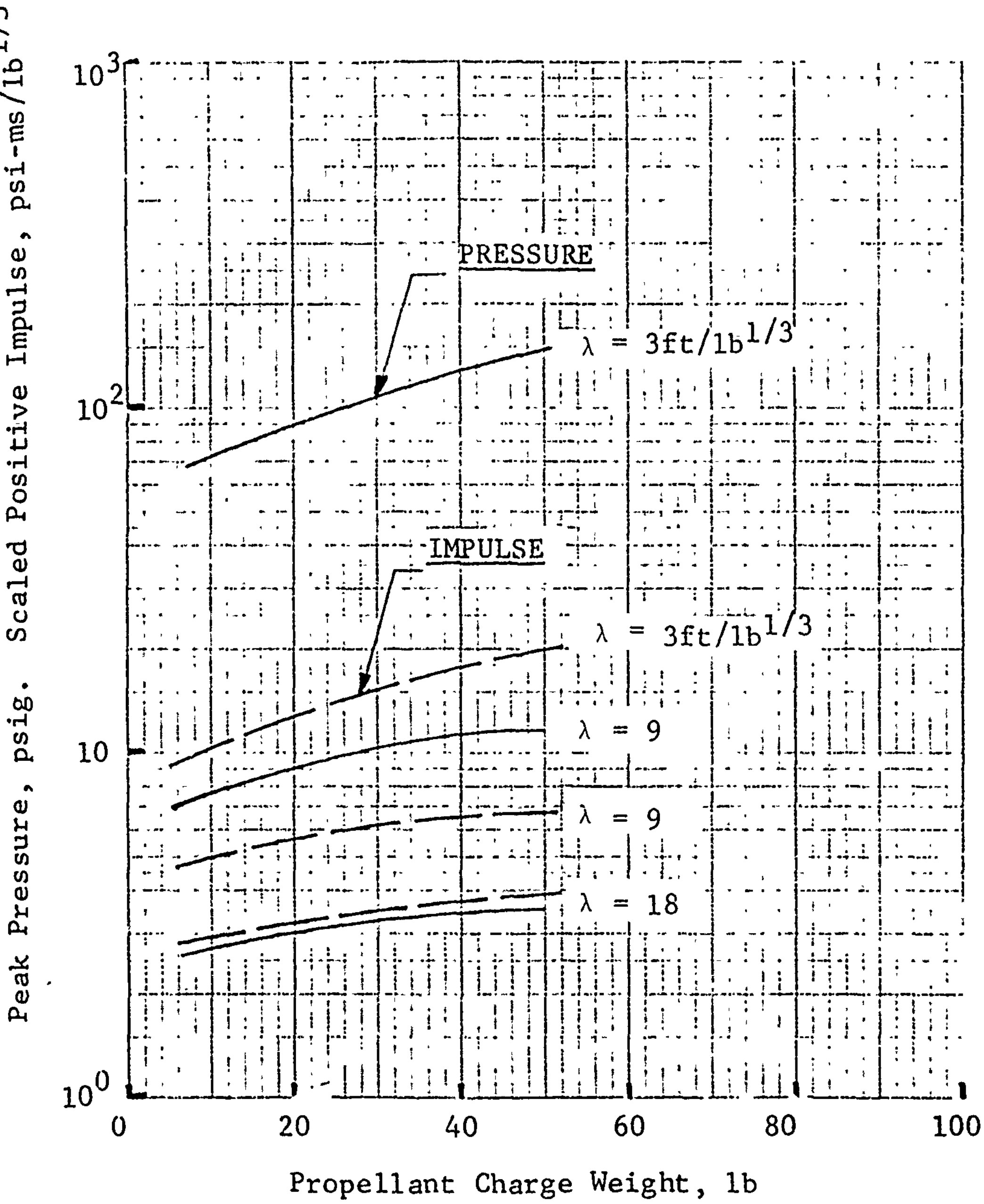


Fig 9 M1-SP closed-hopper configuration scaling

Table 4

M1 multiperforated propellant tests

Test. No.	Propellant Weight (W_P) (lbs)	Booster Weight (W_B) (lbs)	W_B/W_P (percent)	Field Observation
	Shipping Drum Configuration			
M1/MP-1R	55	1.5	2.7	Complete Ignition
M1/MP-2R	55	1.5	2.7	Complete Ignition
M1/MP-3R	35	0.88	2.5	Complete Ignition
M1/MP-4R	35	0.88	2.5	Complete Ignition
	Open Hopper Configuration (IAAP)			
M1/MP-OH1	50	2.5	5.0	Incomplete Ignition
M1/MP-OH2	50	2.5	5.0	Incomplete Ignition
M1/MP-OH3	50	2.5	5.0	Incomplete Ignition
	Closed Hopper Configuration (RAAP)			
M1/MP-CH1	50	2.5	5.0	Incomplete Ignition
M1/MP-CH2	50	2.5	5.0	Incomplete Ignition
M1/MP-CH3	50	2.5	5.0	Incomplete Ignition

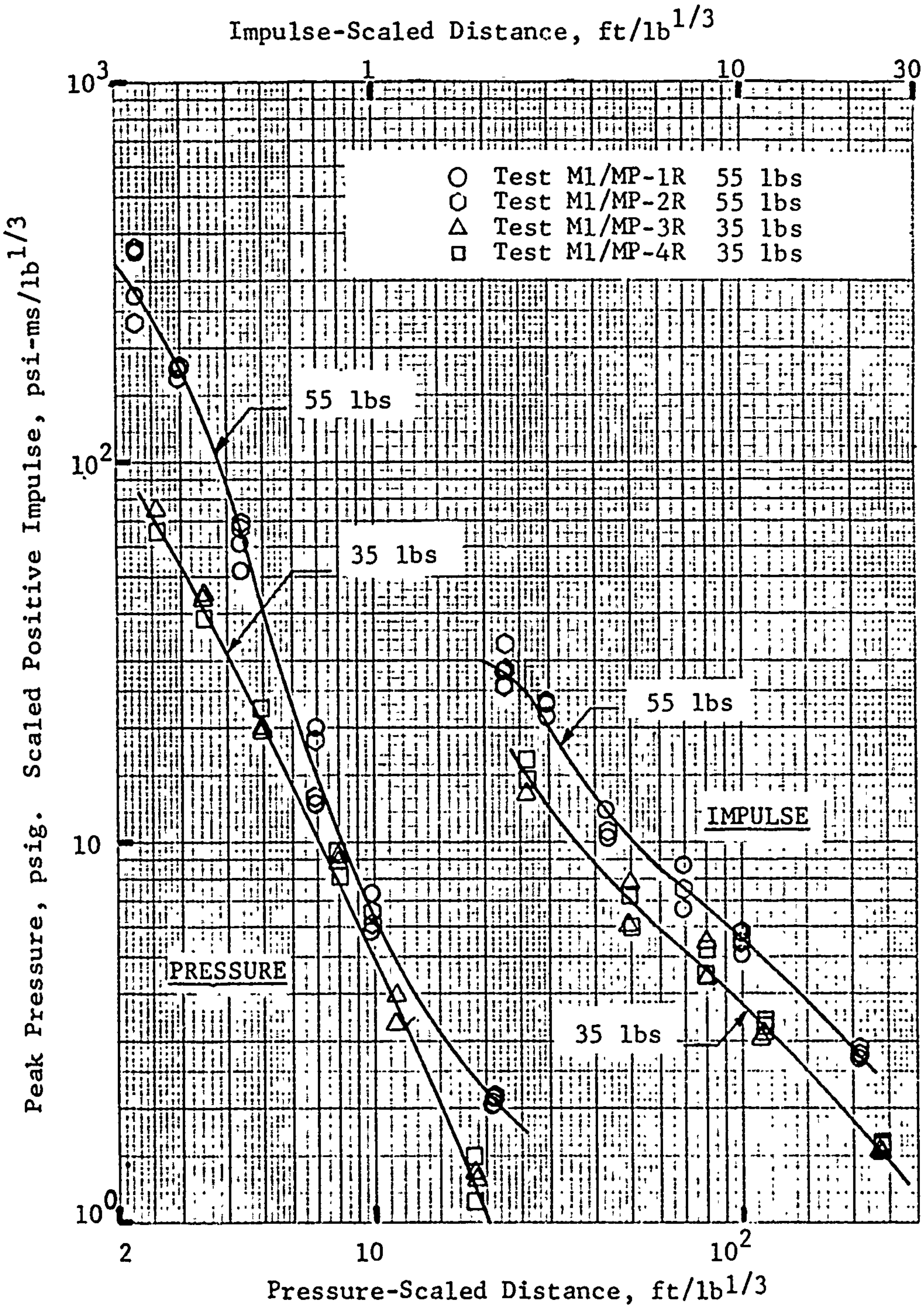


Fig 10 M1-MP shipping drum configuration

Open-Hopper Configuration

Three open-hopper configuration tests were conducted, each with 50 pounds of multiperforated M1 propellant. The blast output results are illustrated in Figure 11. In analyzing the results from Figure 11, a considerable scatter of data points is observed. A consistent deviation from the mean (for pressure and impulse) is observed for all scaled distances. For the peak pressure, the mean deviation is approximately ± 17 percent to ± 16 percent for $\lambda = 2$ to $20\ ft/lb^{1/3}$. In the impulse measurement mode, the mean deviation varies from ± 21 percent to ± 9 percent for respective scaled distances, $\lambda = 2$ to $20\ ft/lb^{1/3}$.

In comparing the blast output levels of multiperforated propellant (MP-M1) and that of the single-perforated (SP-M1) type, one observes that for equal charge weights (50 lb), the characteristic blast output attained by the latter is larger than the level of the former.

Closed-Hopper Configuration

Three closed-hopper configuration tests were conducted with multiperforated type propellant. The blast output results are illustrated in Figure 12. As in the open hopper configuration, a similar performance trend is apparent. That is, the single-perforated M1 propellant yielded a higher blast output than the multiperforated M1 type. A considerable amount of scatter appears in the data representation (Fig 12); specifically, for the small scaled distances ($2\ ft/lb^{1/3}$) the deviation is large. This trend is evident for all of the hopper configuration tests.

TNT Equivalency Calculations

TNT equivalency calculations were performed for the nominal 50-pound scaled drum configuration and for the open- and closed-hopper tests for each M1 propellant granulation. The TNT equivalency curves for each test configuration were computed from the best fit curves for pressure and impulse as a function of scaled distance. The TNT equivalency is defined as the ratio of the weight of TNT to the weight of the test propellant that would produce the same overpressure (or impulse) at the same distance. The TNT peak pressure and scaled impulse curves used to make the TNT equivalency calculations for this report are illustrated in Figure 13. These curves must be used when converting TNT equivalency numbers back into pressure and positive impulse values.

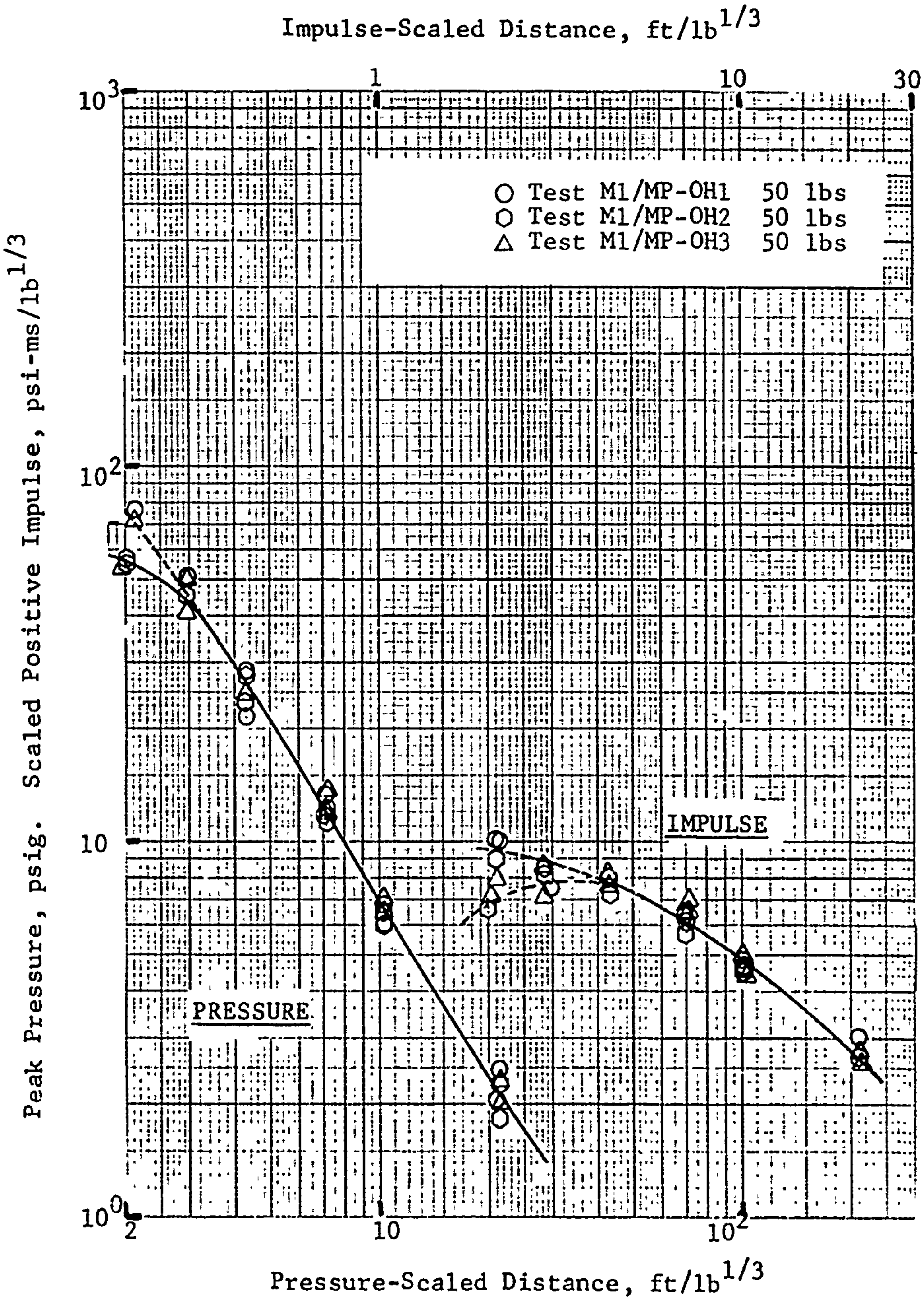


Fig 11 M1-MP open-hopper configuration, 50 lb

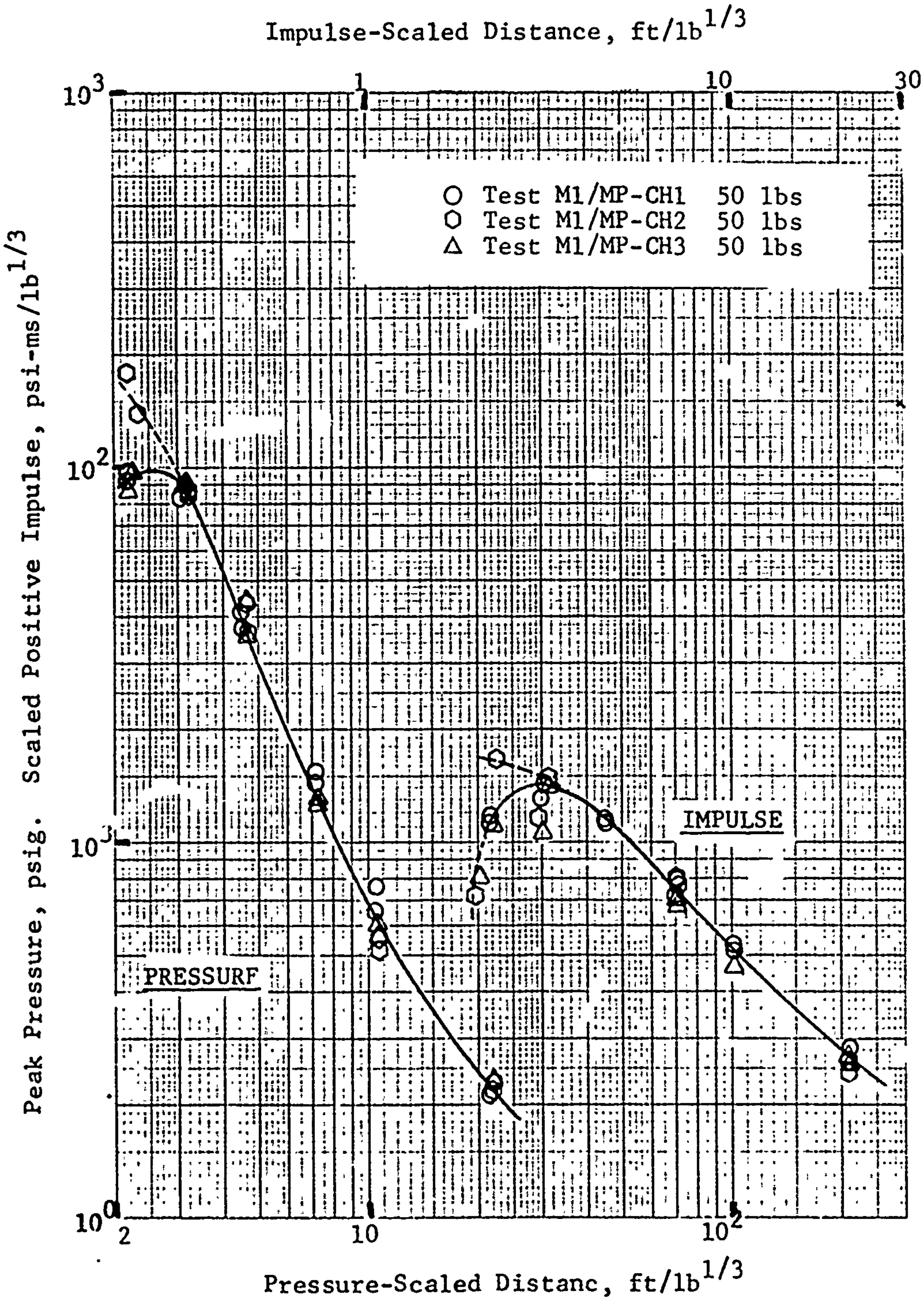


Fig 12 M1-MP closed-hopper configuration

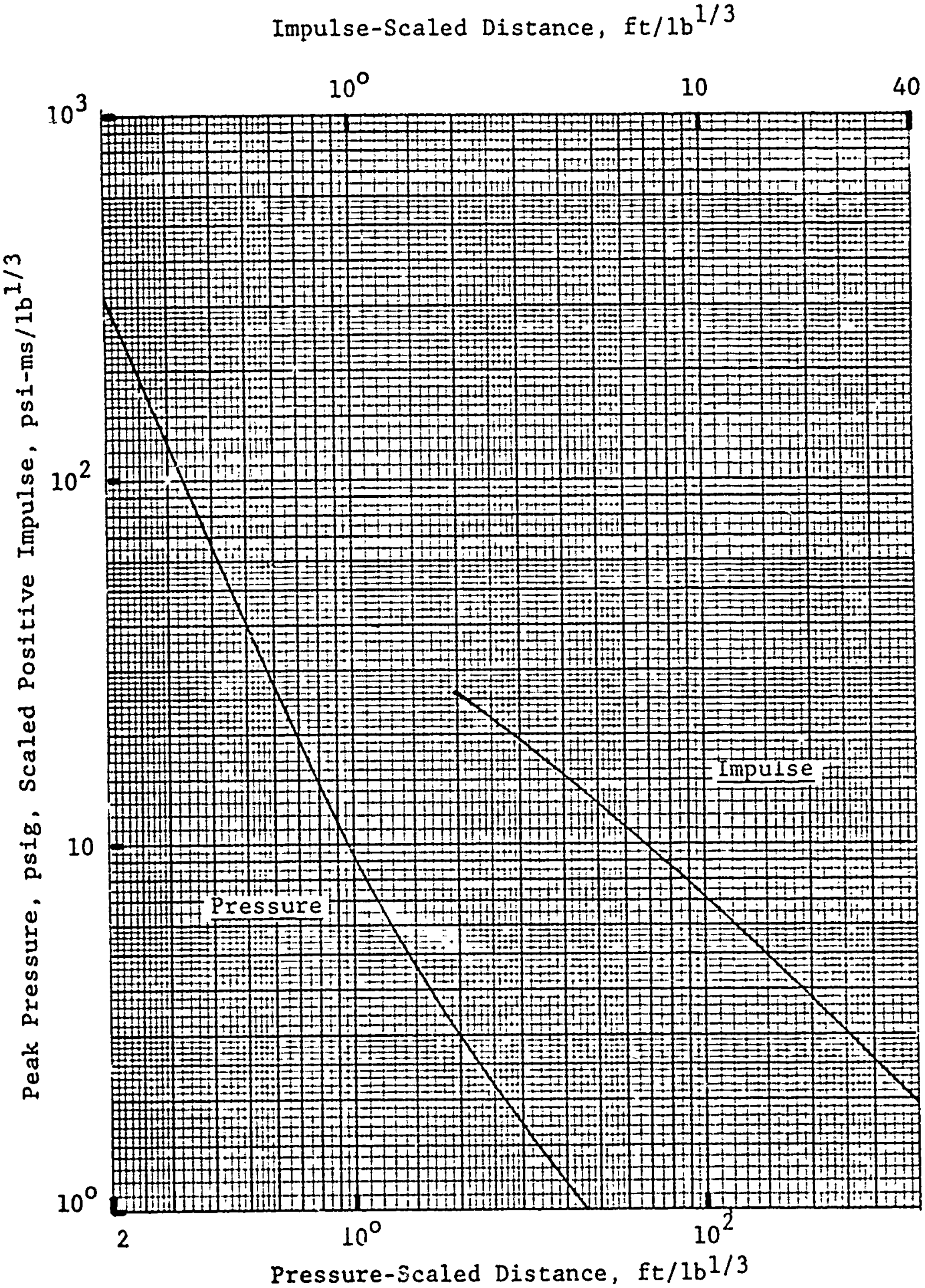


Fig 13 TNT peak pressure and positive impulse

Figure 14 illustrates the difference in the TNT equivalency results for SP and MP M1 propellants. Although the charge weights (SP=43, MP=55) are relatively the same, the single-perforated propellant produced a larger blast output (peak pressure and impulse) than the multiperforated type. In addition, because of the identical blast output behavior of single-perforated propellant for the 27- and 43 pound charge weight (scaled drum configuration), the TNT equivalency curves for the two charge weights are identical. If one deduces that the identical peak pressure and impulse behavior of the two charge weights are an indication that the maximum output level has been reached, then a logical conclusion would be that any further increase of charge weight (aspect ratios being constant) would result in similar blast responses. That is, the present SP data could be used for predicting the blast outputs for full-sized shipping containers (for SP-M1 propellant).

In contrast to the above statement that was made for the single-perforated propellant, the results obtained for the 35- and 55-pound MP-M1 charge weights (drum configuration) do not define an identical blast output trend. Because of the difference in the peak pressure and impulse measurements for the two charge weights, any speculation that the blast output of the larger charge weight is an upper bound is inconclusive. A justifiable projection of the full-scaled drum configuration based on the blast output of the 55-pound charge weight (MP) is not directly possible. An indirect approach, however, is feasible. For any particular configuration and charge weight, the blast output for the MP propellant is always smaller than that for the SP propellant. The SP characteristic blast output can be utilized as an upper bound for the blast output of MP propellant.

TNT equivalencies for the hopper configuration tests are illustrated in Figures 15 and 16 for both the SP and MP propellants. The closed-hopper configuration (RAAP) gave higher blast outputs than the open-hopper configuration (IAAP) and consequently higher TNT equivalencies.

In the single-perforated closed-hopper test mode, the scaled blast output increases with charge weight of propellants at scaled distances less than 9 ft/lb$^{1/3}$. Indications are that the maximum output or limit has not been attained.

With this observation, expectations are that for the full-size closed hopper, a TNT equivalency equal to or greater than that for the 50-pound test would be attained. An equivalent generalization can also be made for the full-size open-hopper configuration loaded with SP or MP propellant.

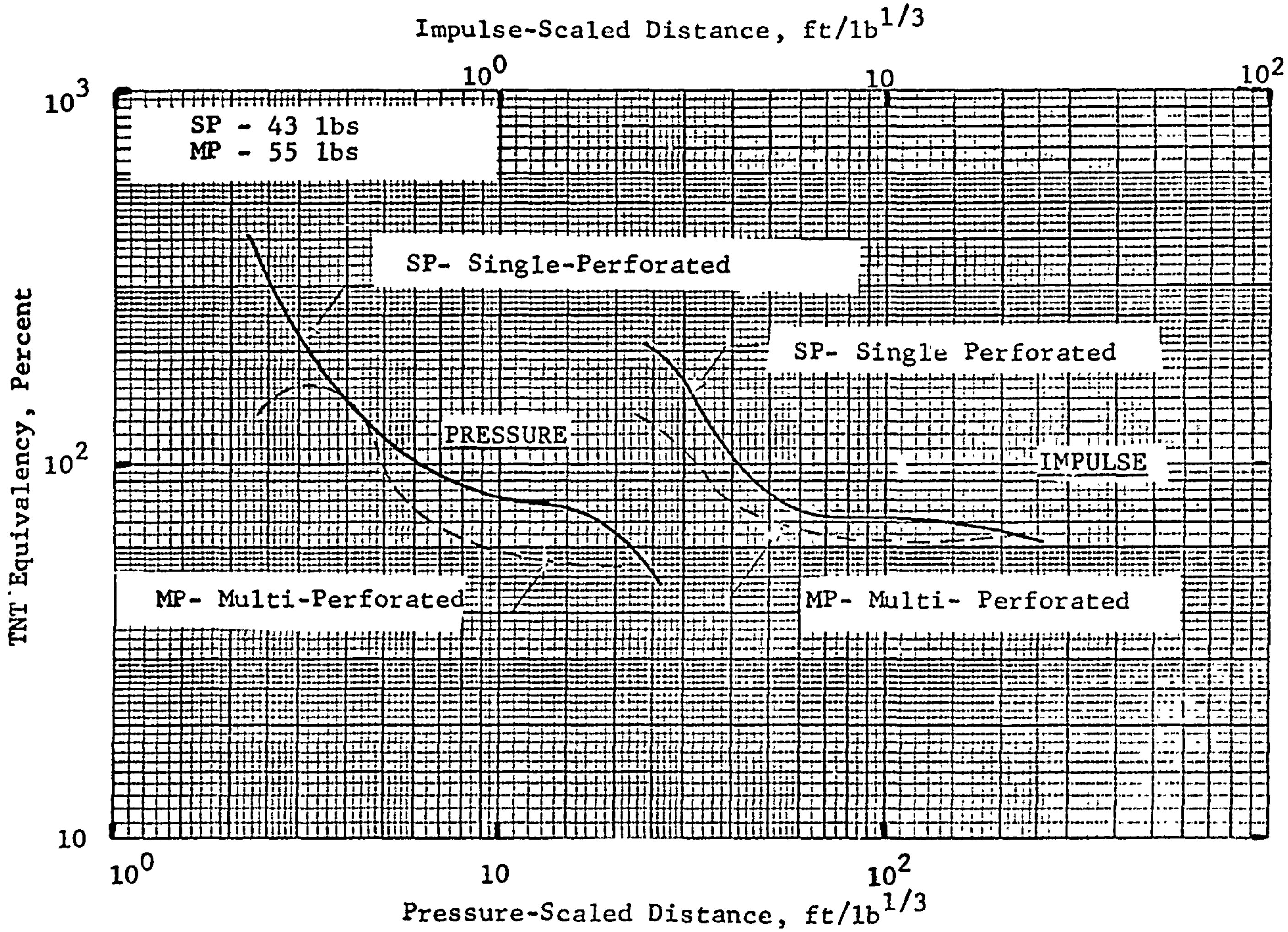


Fig 14 M1-SP/MP TNT equivalency, shipping drum configuration

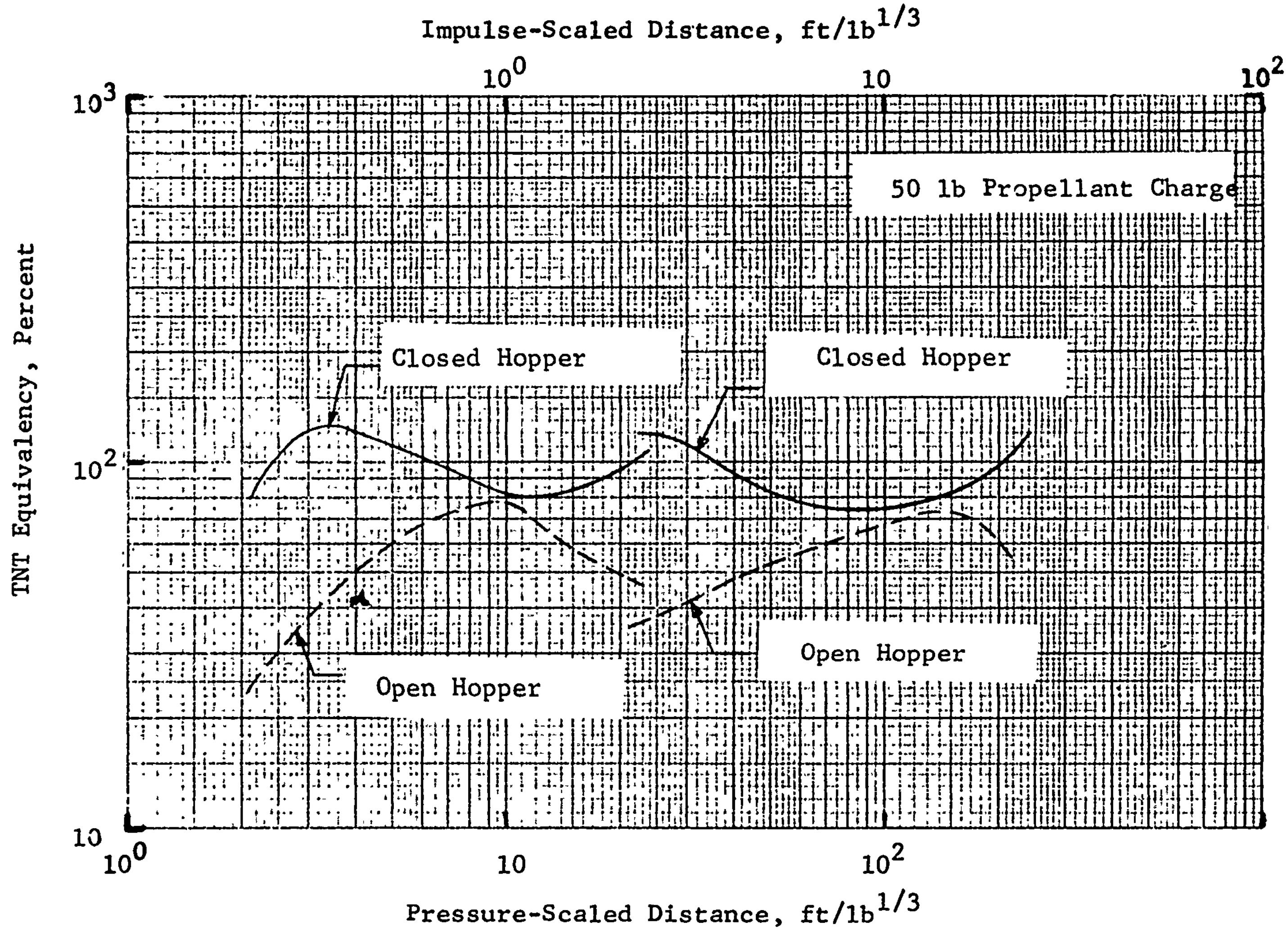


Fig 15 M1-SP TNT equivalency, hopper configurations

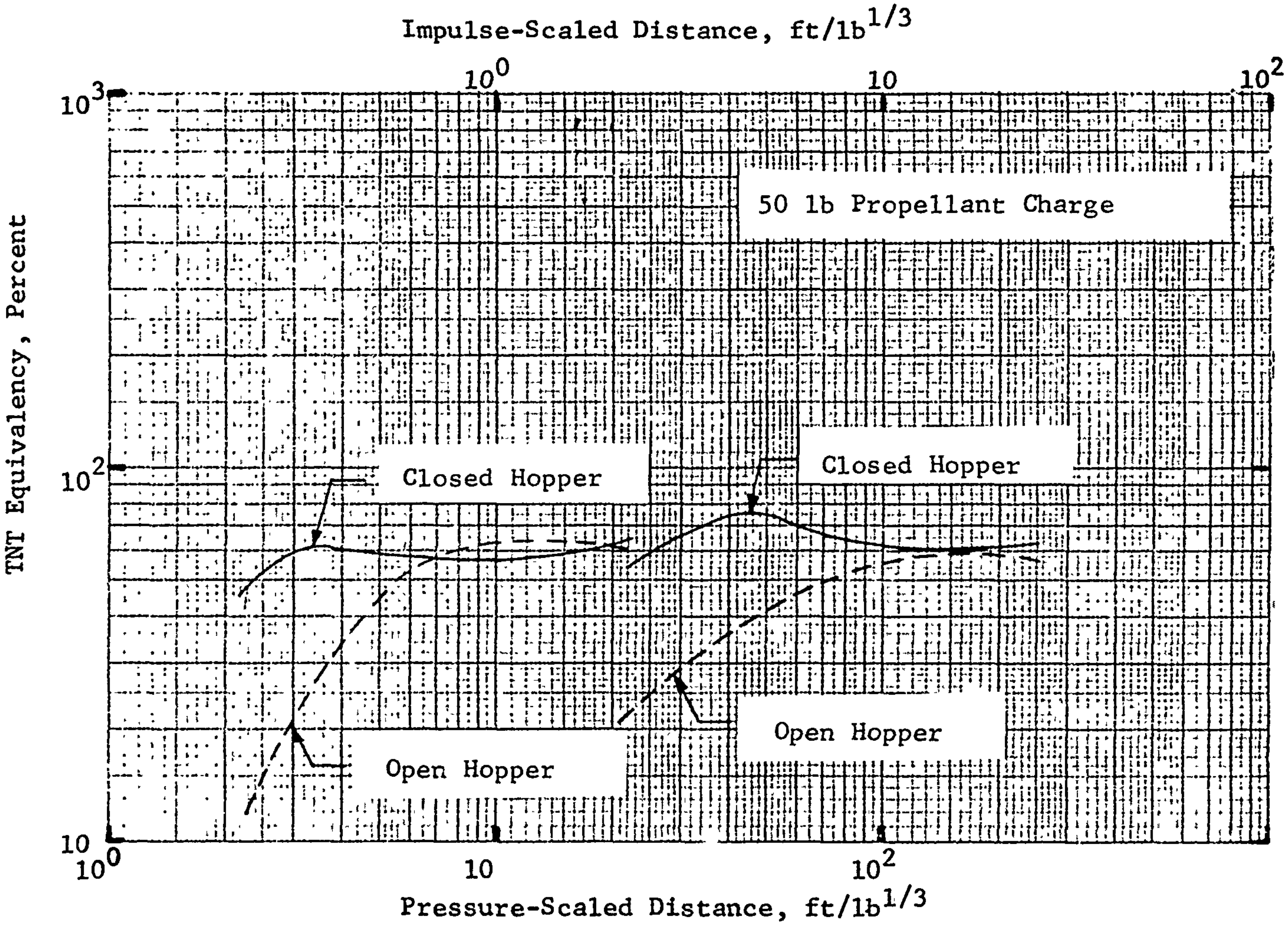


Fig 16 M1-MP TNT equivalency, hopper configurations

Maximum TNT equivalency curves are illustrated in Figures 17 through 22 for the three geometric configurations and the two M1 propellants. In addition, Table 5 indicates the relative maximum TNT equivalency profile at scaled distances of 3, 9, and 18 $ft/lb^{1/3}$.

CONCLUSION

The average TNT equivalencies computed for M1 propellant, single-perforated (.013 inch web size) and multiperforated (.025 inch web size) tested in three geometrical configurations, are summarized in Table 6. In all of the scaled configurations the volumes and relative charge weights were manipulated to provide equivalent aspect ratios relative to the full-size configuration.

Tests with single-perforated M1 propellant in scaled drum containers indicated that the results could be used to project the blast output level from full-size shipping drums.

The multiperforated M1 propellant always yielded lower blast outputs than the single-perforated propellant in similar configurations and charge weights. Although the test with multiperforated M1 propellant indicated that the data could not be scaled upward to the full-size shipping drum container, the results from the tests with single-perforated propellant can be used as an upper bound for TNT equivalency determination for full-size multiperforated propellant.

Tests with single-perforated M1 propellant in the closed-hopper configuration showed that scaling or projecting the data obtained to full-size hopper units was not feasible at scaled distances less than 9 $ft/lb^{1/3}$.

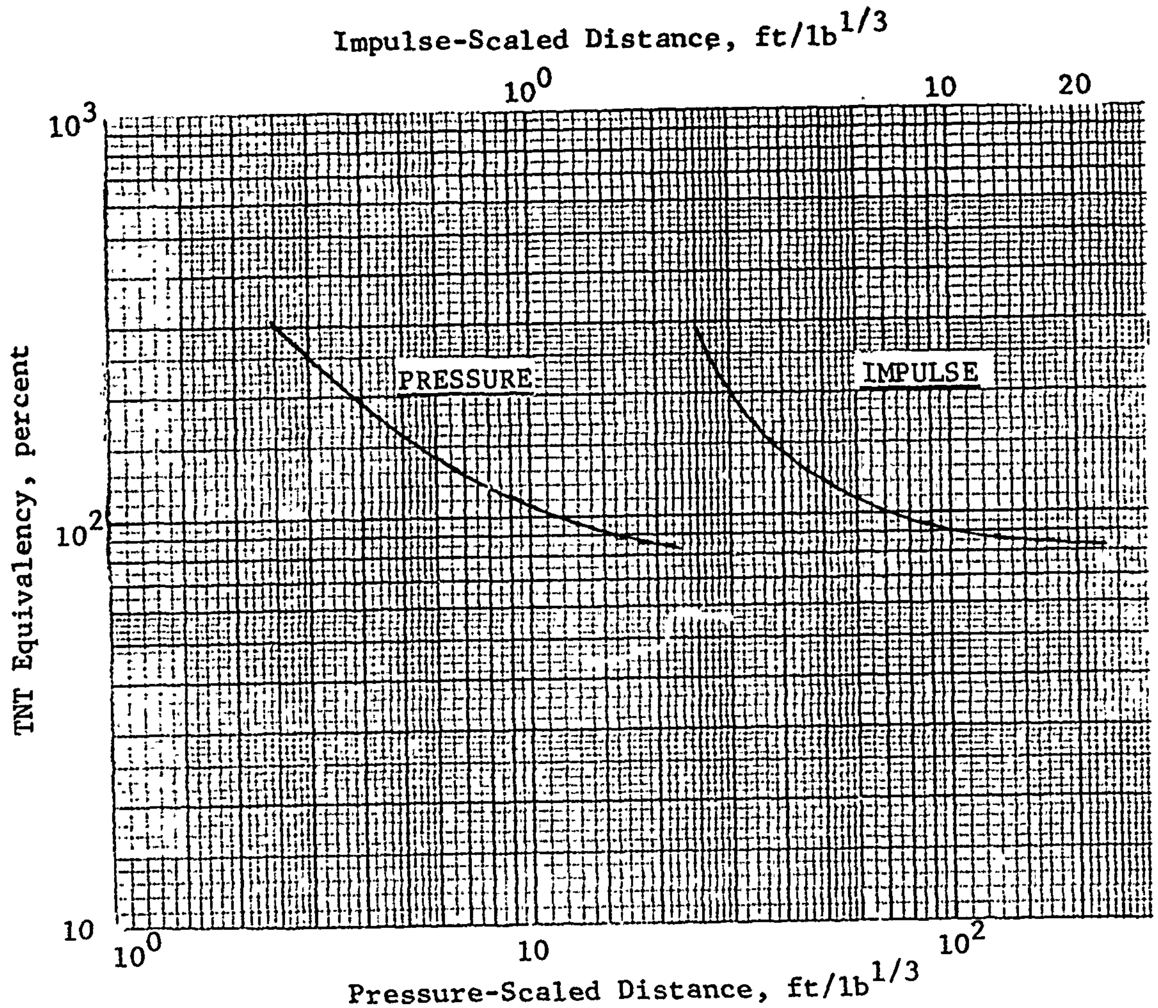


Fig 17 Maximum TNT equivalency, M1-SP shipping drum configuration, 43 lb

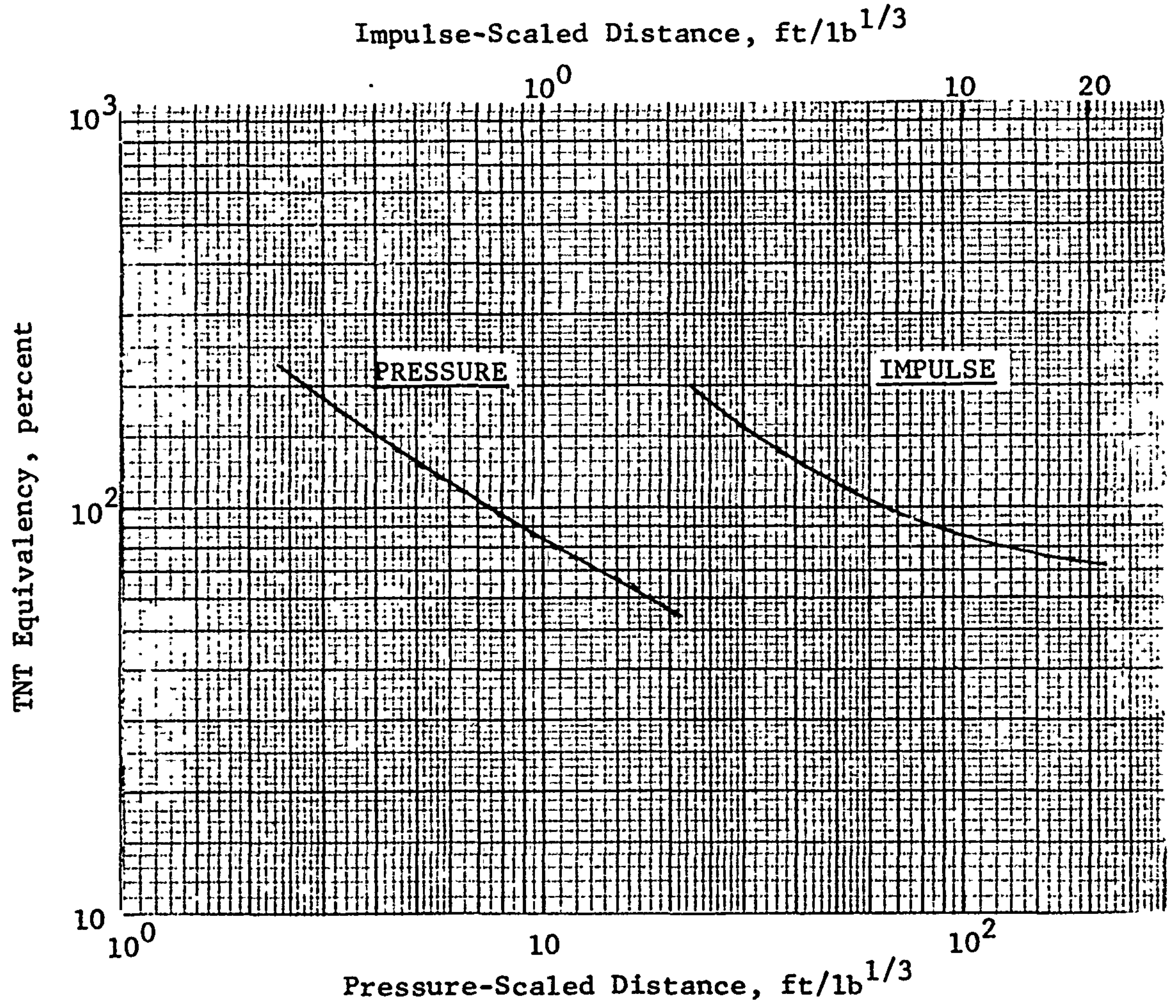


Fig ˜8 Maximum TNT equivalency, M1-MP shipping drum configuration, 55 lb

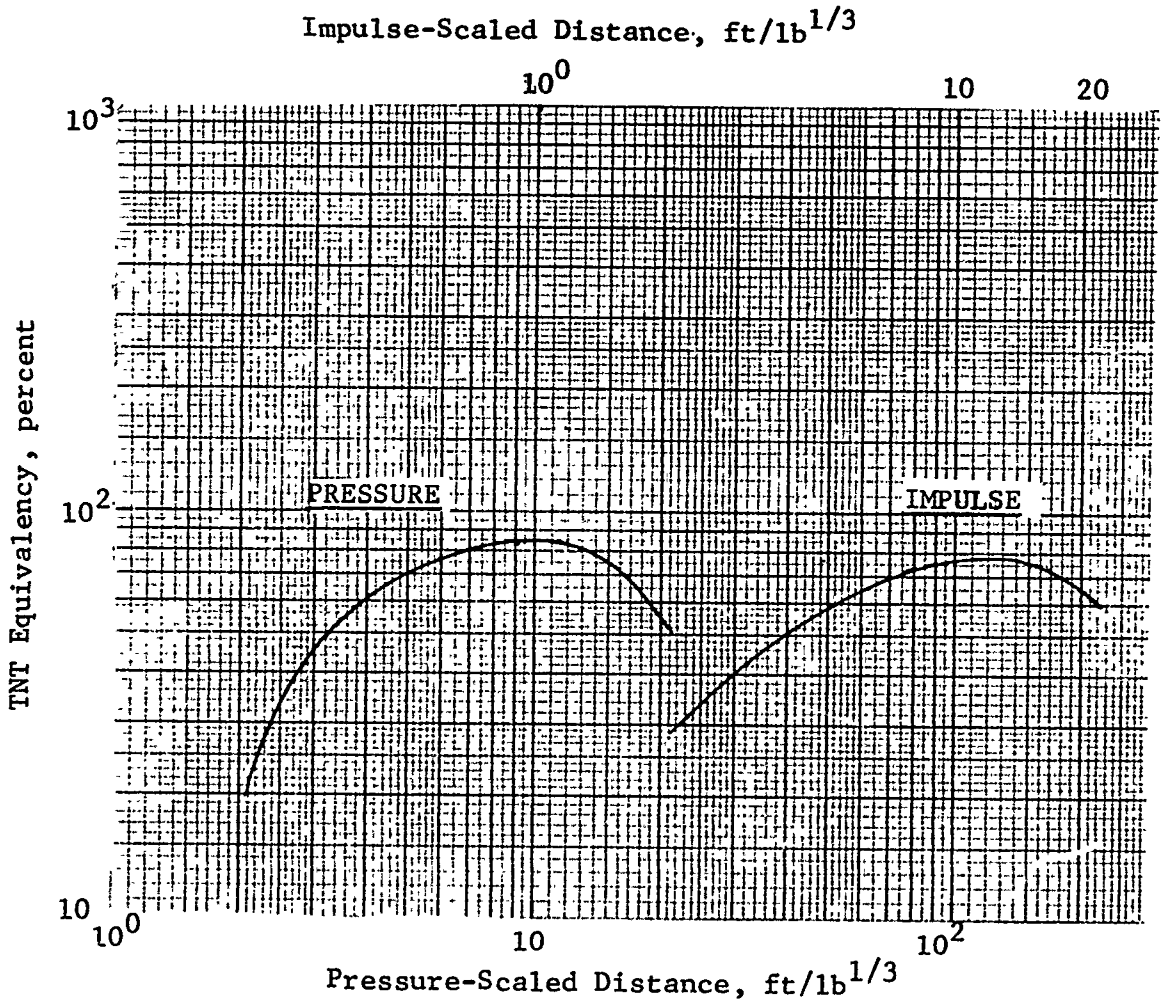


Fig 19 Maximum TNT equivalency, M1-SP open-hopper configuration, 50 lb

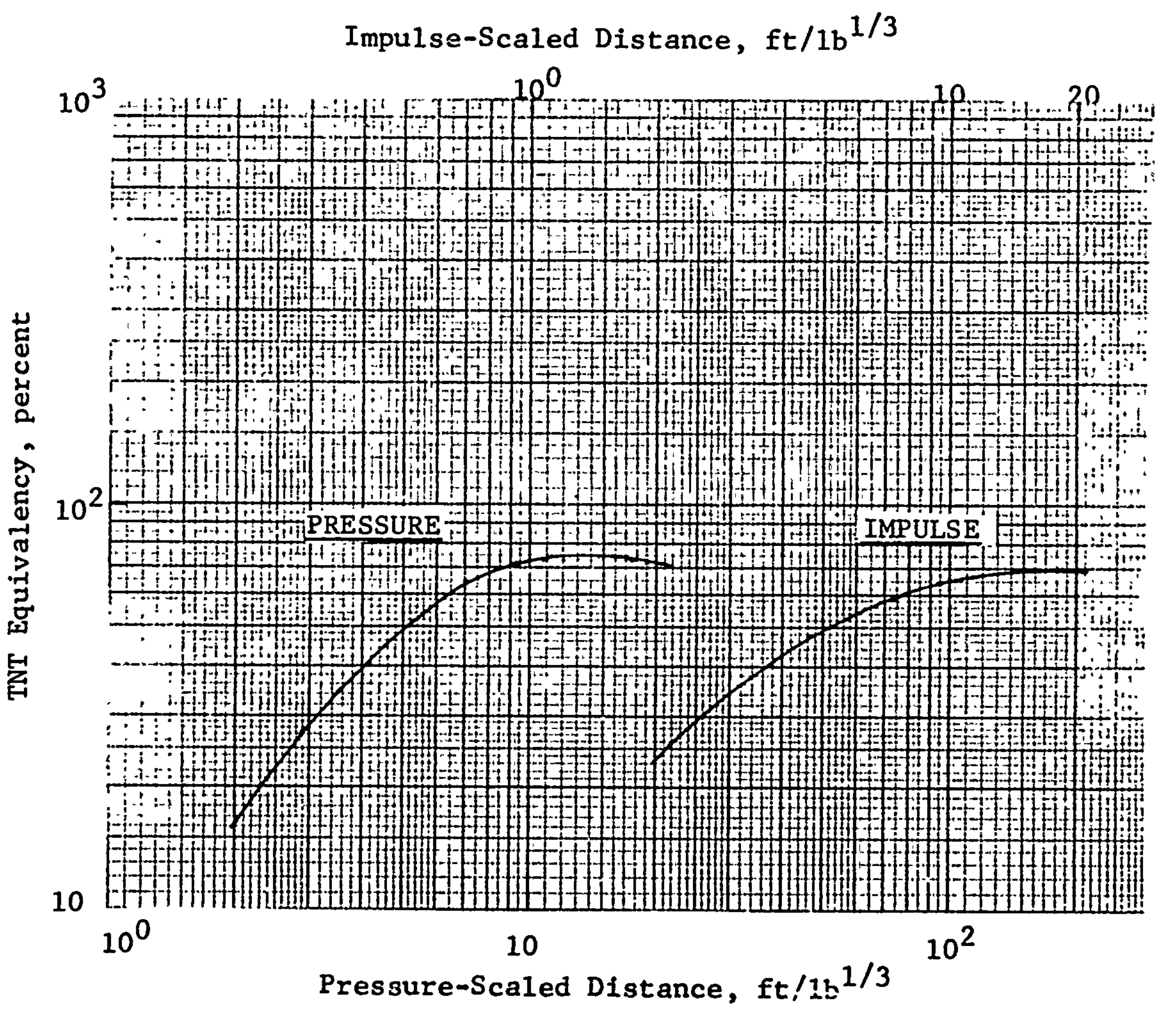


Fig 20 Maximum TNT equivalency, M1-MP open-hopper configuration, 50 lb

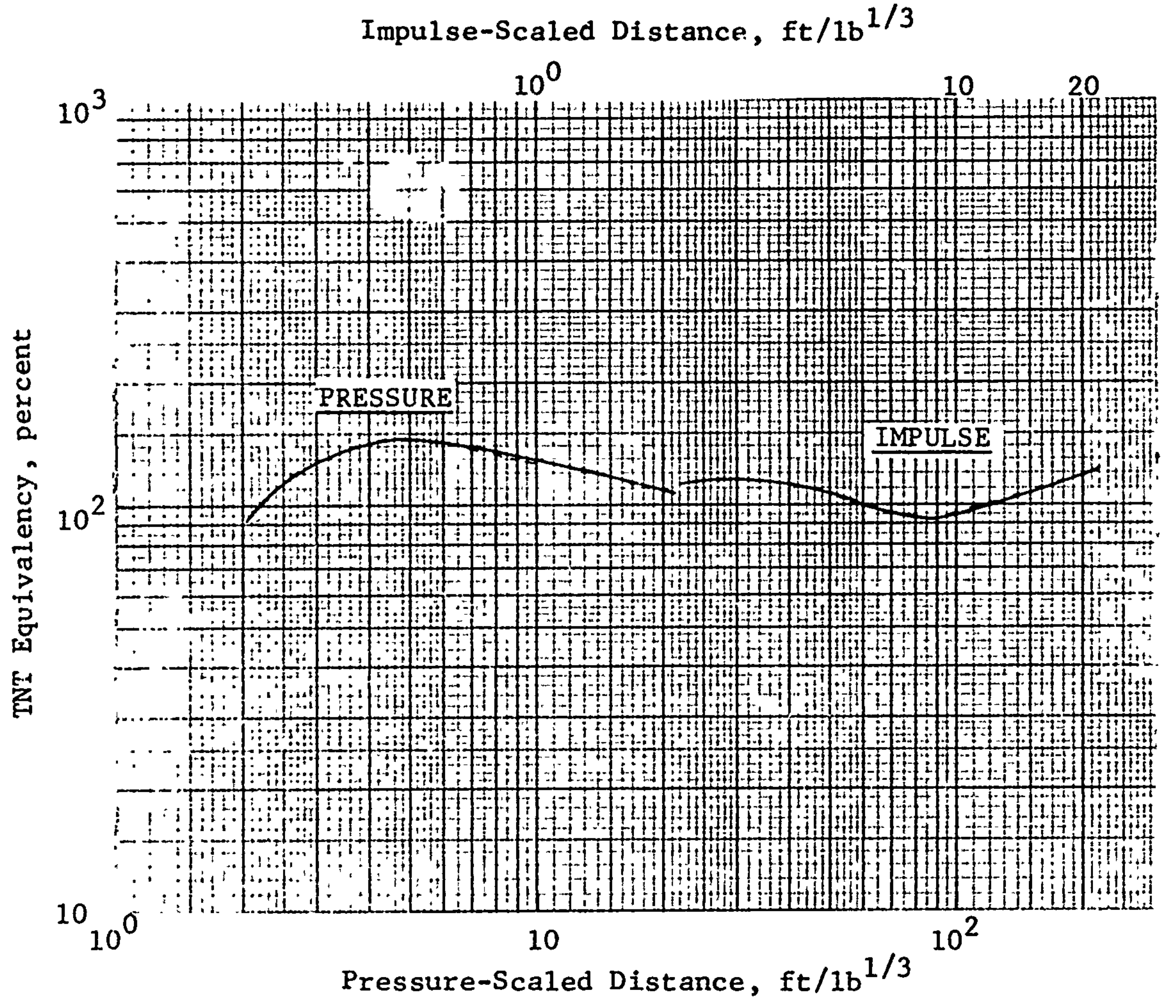


Fig 21 Maximum TNT equivalency, M1-SP closed-hopper configuration, 50 lb

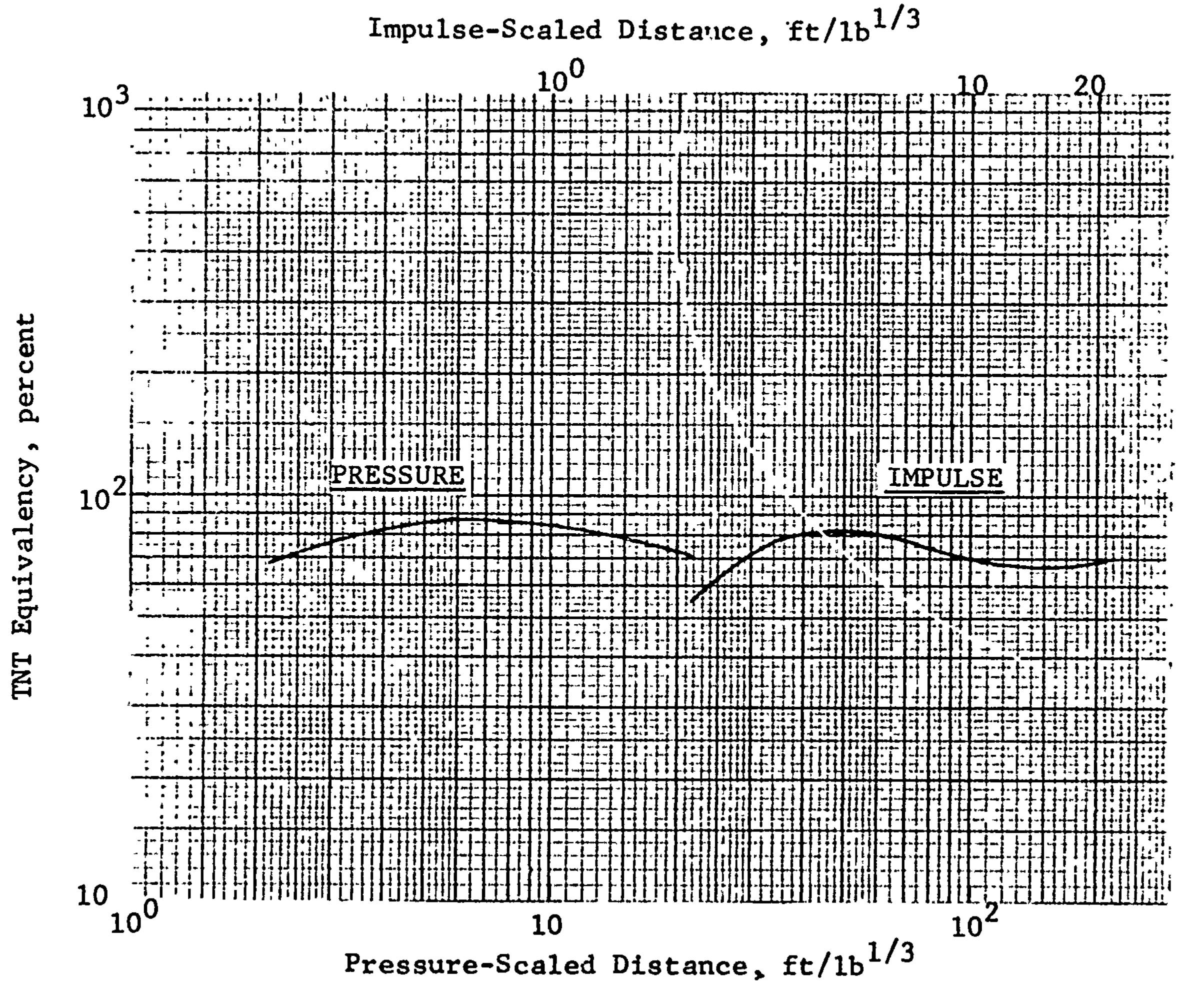


Fig 22 Maximum TNT equivalency, M1-MP closed-hopper configuration, 50 lb

Table 5

Maximum TNT equivalency profile of M1 propellant

Configuration	Charge Weight, lb	Scaled distance, $ft/lb^{1/3}$ 3 P	3 I	9 P	9 I	18 P	18 I
Single-perforated	Propellant			(.013-inch web size)			
Shipping Drum	43	250	190	112	92	86	84
Open Hoppers	50	45	42	85	77	65	71
Closed Hoppers	50	128	118	130	100	110	116
Multiperforated	Propellant			(.040-inch web size)			
Shipping Drum	55	185	155	88	90	60	74
Open Hoppers	50	29	34	70	63	72	69
Closed Hoppers	50	77	72	85	71	75	68

Table 6

TNT equivalency* profile of M1 propellant

Configuration	Charge Weight, lb	Scaled distance, ft/lb$^{1/3}$					
		3		9		20	
		P	I	P	I	P	I
Single-perforated propellant (0.013-inch web size)							
Shipping Drum	43	220	165	85	75	65	65
Open Hoppers	50	40	40	80	65	50	60
Closed Hoppers	50	120	110	85	75	95	95
Multiperforated propellant (0.040-inch web size)							
Shipping Drum	50	160	110	60	65	55	65
Open Hoppers	50	20	30	60	55	60	60
Closed Hoppers	50	60	65	55	60	60	60

*TNT equivalency expressed as percent.

APPENDIX A

TEST DATA AND COMPUTED TNT EQUIVALENCY DATA

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$1/W^{1/3}$ $(PSI-MS/LB^{1/3})$	LAMBDA-P $(FT/LB^{1/3})$	LAMBDA-I $(FT/LB^{1/3})$	FQ-P (%)	FQ-I (%)
M1MP-18 55 LBS (1.5 LB) CYLINDER L/D = 1.7							
	8.80	353.00	27.91	2.30	2.30	176.83	134.09
	8.81	268.00	27.64	2.30	2.30	117.42	132.09
	11.77	165.00	21.29	3.07	3.07	141.84	123.05
	11.97	175.00	23.84	3.13	3.12	162.32	152.61
	16.97	51.20	10.70	4.41	4.38	88.61	62.66
	16.98	61.50	12.10	4.42	4.40	113.65	77.25
	26.98	20.00	8.72	7.02	7.00	102.86	85.07
	27.02	13.50	6.62	6.97	6.96	57.52	54.[illegible]
	39.53	5.76	5.41	10.15	10.22	44.87	67.01
	39.67	7.29	5.06	10.27	10.24	49.81	60.51
	80.65	2.13	2.87	20.[illegible]	20.87	54.17	69.50
	80.72	2.00	2.74	20.74	20.87	46.92	64.60

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	FQ-P (%)	FQ-I (%)
M1MP-2R 55 LBS (1.5 LB) CYLINDER L/D = 1.7							
	8.80	359.00	33.19	2.30	2.30	181.41	181.26
	8.81	236.00	25.53	2.29	2.29	97.19	115.04
	11.77	111.00	- -	3.05	- -	81.33	- -
	11.97	176.00	23.70	3.13	3.12	163.63	151.16
	16.97	68.90	12.90	4.43	4.40	132.05	85.92
	16.98	68.10	10.56	4.43	4.39	130.24	61.40
	26.98	13.00	6.06	6.95	6.93	53.95	46.63
	27.02	18.30	7.42	7.02	6.99	90.91	65.30
	39.53	6.14	5.72	10.17	10.24	50.60	73.54
	39.67	6.60	5.41	10.24	10.26	58.44	67.36
	80.65	2.07	2.69	20.75	20.84	50.71	62.55
	80.72	2.12	2.85	20.80	20.89	53.74	68.58

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EW-P (%)	EQ-I (%)
M1MP-3R 35 LBS (400GM) CYLINDER L/D = 1.7							
	8.80	307.00	20.97	2.68	2.66	227.31	99.66
	8.81	75.30	13.24	2.61	2.63	30.31	45.23
	11.77	44.70	6.43	3.50	3.43	37.32	19.44
	11.97	44.10	14.21	3.57	3.61	38.67	77.33
	16.97	19.50	7.74	5.05	5.07	37.00	45.01
	16.98	19.90	6.03	5.06	5.02	38.21	29.58
	26.98	9.34	5.36	8.09	8.07	51.11	47.36
	27.02	9.01	4.46	8.09	8.03	48.31	35.06
	39.53	3.35	3.12	11.61	11.74	24.25	34.29
	39.67	3.95	3.03	11.79	11.77	35.06	32.82
	80.65	1.31	1.56	23.78	23.93	27.27	33.49
	80.72	1.30	1.58	23.79	23.97	26.82	34.27

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ ($PSI\text{-}MS/LB^{1/3}$)	LAMBDA-P ($FT/LB^{1/3}$)	LAMBDA-I ($FT/LB^{1/3}$)	FQ-P (%)	FQ-I (%)
M1MP-4R 35 LBS (400GM) CYLINDER L/D = 1.7							
	8.80	66.30	16.71	2.59	2.65	25.11	67.44
	8.81	143.00	14.45	2.66	2.64	75.48	52.59
	11.77	38.30	9.09	3.48	3.50	29.95	35.34
	11.97	57.90	13.22	3.59	3.61	56.40	68.43
	16.97	22.60	7.37	5.08	5.06	46.02	41.43
	16.98	16.40	5.97	5.01	5.02	28.39	29.06
	26.98	7.84	5.26	8.03	8.07	37.72	46.02
	27.02	9.54	4.58	8.10	8.04	53.21	36.69
	39.55	4.76	3.21	11.85	11.76	50.59	36.00
	39.67	2.70	3.18	11.39	11.79	14.76	35.60
	80.65	1.49	1.55	24.01	23.93	37.70	33.07
	80.72	1.13	1.57	23.44	23.96	18.52	33.74

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ $(PSI-MS/LB^{1/3})$	LAMBDA-P $(FT/LB^{1/3})$	LAMBDA-I $(FT/LB^{1/3})$	EQ-P (%)	EQ-I (%)
MISP-1R 43 LBS (1.5 LB) CYLINDER L/D = 1.7							
	8.80	421.00	37.46	2.50	2.50	296.00	248.13
	8.81	325.00	31.73	2.50	2.50	200.35	186.14
	11.77	138.00	16.02	3.33	3.31	141.13	102.69
	16.97	69.70	13.00	4.80	4.77	171.53	96.90
	16.98	64.40	10.63	4.80	4.75	154.60	69.09
	26.98	18.10	8.57	7.61	7.58	113.91	92.40
	27.02	15.50	7.65	7.59	7.57	90.94	76.71
	39.53	6.96	5.46	11.09	11.08	81.34	76.33
	39.67	6.99	5.41	11.13	11.11	82.88	75.42
	80.65	1.99	2.86	22.48	22.61	59.15	77.52
	80.72	2.00	2.89	22.51	22.63	60.02	78.87

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1SP-2R 43 LBS (1.5 LB) CYLINDER L/D = 1.7							
	8.80	271.00	34.02	2.49	2.50	152.16	209.85
	8.81	411.00	33.74	2.50	2.50	266.24	207.09
	11.77	186.00	14.29	3.34	3.29	215.00	69.04
	11.97	126.00	22.03	3.38	3.38	130.81	148.21
	16.97	35.60	12.16	4.75	4.77	68.97	86.63
	16.98	68.90	10.31	4.81	4.74	169.21	65.63
	26.98	18.30	8.57	7.61	7.58	115.75	92.40
	27.02	14.60	7.48	7.58	7.57	83.04	73.86
	39.53	7.66	5.81	11.12	11.10	96.28	84.34
	39.67	6.04	5.46	11.08	11.12	63.49	76.73
	80.65	2.28	2.80	22.62	22.59	80.93	75.07
	80.72	1.83	2.80	22.39	22.61	48.58	75.05

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ $(PSI-MS/LB^{1/3})$	LAMBDA-P $(FT/LB^{1/3})$	LAMBDA-I $(FT/LB^{1/3})$	EQ-P (%)	EQ-I (%)
M1SP-3R 27 LBS (400GM) CYLINDER L/D = 1.7							
	8.80	336.00	54.21	2.92	2.93	340.11	575.48
	8.81	221.00	26.42	2.92	2.91	182.65	166.05
	11.77	78.20	16.46	3.87	3.88	104.50	108.63
	11.97	128.00	12.66	3.97	3.92	215.89	71.17
	16.97	31.70	9.02	5.58	5.54	96.17	65.16
	16.98	19.90	7.29	5.51	5.50	49.54	45.63
	26.98	12.80	7.09	8.89	8.85	110.09	84.34
	27.02	11.10	5.98	8.87	8.82	88.39	63.89
	39.53	3.90	4.48	12.79	12.93	43.74	69.53
	39.67	4.99	3.74	12.99	12.90	72.69	52.14
	80.65	1.41	2.12	26.08	26.32	42.61	61.54
	80.72	1.48	2.09	26.19	26.33	48.21	60.25

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ ($PSI-MS/LB^{1/3}$)	LAMBDA-P ($FT/LB^{1/3}$)	LAMBDA-I ($FT/LB^{1/3}$)	EQ-P (%)	EQ-I (%)
MISP-4R 27 LBS (400GM) CYLINDER L/D = 1.7							
	8.80	293.00	35.16	2.92	2.92	274.97	271.43
	8.81	151.00	25.75	2.90	2.91	105.71	158.87
	11.77	59.70	12.76	3.85	3.85	72.28	70.44
	11.97	119.00	19.59	3.96	3.96	195.32	149.38
	16.97	29.30	9.96	5.57	5.56	86.25	76.99
	16.98	32.30	7.32	5.58	5.50	98.86	45.99
	26.98	10.30	6.85	8.84	8.85	77.85	79.80
	27.02	9.58	5.98	8.84	8.82	69.46	63.89
	39.53	3.98	4.48	12.81	12.93	45.65	69.53
	39.67	4.21	3.94	12.90	12.92	51.86	56.80
	80.65	1.48	2.04	26.17	26.28	48.11	57.60
	80.72	1.49	2.16	26.20	26.36	49.01	63.48

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ $(PSI\text{-}MS/LB^{1/3})$	LAMBDA-P $(FT/LB^{1/3})$	LAMBDA-I $(FT/LB^{1/3})$	FO-P (%)	FO-I (%)
M1SP-OHI 50 LBS (2.5 LB)							
	8.76	84.70	- -	2.18	- -	20.65	- -
	8.76	103.00	22.42	2.25	2.33	29.28	93.85
	11.72	- -	8.30	- -	2.95	- -	24.12
	11.99	59.80	11.91	3.09	3.12	37.54	47.51
	16.95	39.10	9.33	4.46	4.43	64.69	50.68
	16.99	- -	8.32	- -	4.41	- -	41.76
	26.97	18.60	7.60	7.17	7.12	99.32	69.59
	27.01	15.70	6.96	7.14	7.10	77.17	60.22
	39.47	7.92	5.54	10.46	10.42	84.81	71.66
	39.75	6.61	5.13	10.45	10.46	62.41	63.73
	56.92	4.59	- -	15.14	- -	98.71	- -
	57.06	3.52	3.99	14.97	15.07	57.34	72.09

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1SP-OH2 50 LBS (2.5 LB)							
	8.76	- -	6.46	- -	2.01	- -	9.56
	8.81	90.70	11.31	2.21	2.24	23.68	28.03
	11.72	53.70	8.33	2.99	2.95	29.38	24.27
	11.99	58.30	10.90	3.09	3.11	36.12	40.68
	16.95	32.20	8.74	4.42	4.41	48.88	45.31
	16.99	30.20	9.63	4.42	4.45	44.78	53.77
	26.97	11.50	- -	7.02	- -	46.24	- -
	27.01	14.20	6.27	7.11	7.05	65.88	50.44
	39.47	7.71	5.49	10.45	10.42	80.86	70.49
	39.75	6.77	5.66	10.47	10.51	65.28	74.83
	80.69	2.02	2.44	21.07	21.14	50.32	54.95
	80.72	1.94	2.54	21.00	21.19	45.60	58.65

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1SP-OH3 50 LBS (2.5 LB)							
	8.76	94.90	6.86	2.21	2.04	24.98	10.77
	8.81	- -	10.58	- -	2.22	- -	24.75
	11.72	- -	8.39	- -	2.95	- -	24.58
	11.99	59.50	10.15	3.09	3.09	37.25	35.81
	16.95	34.80	9.52	4.44	4.43	54.79	52.52
	16.99	- -	8.85	- -	4.42	- -	46.48
	26.97	4.84	7.49	5.81	7.11	6.17	67.90
	27.01	14.80	6.88	7.13	7.09	70.36	59.01
	39.47	7.45	5.21	10.44	10.39	76.04	64.73
	39.75	7.21	5.35	10.50	10.48	73.31	68.32
	80.69	- -	3.40	- -	21.44	- -	93.75
	80.72	1.91	2.41	20.97	21.13	43.86	53.98

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	FD-P (%)	FD-I (%)
MIMP-OH1 50 LBS (2.5 LB)							
	8.76	- -	10.34	- -	2.20	- -	23.54
	8.81	78.50	10.44	2.17	2.22	18.54	24.13
	11.72	50.50	11.11	2.97	3.04	26.54	40.72
	11.99	71.60	- -	3.13	- -	49.05	- -
	16.95	26.10	- -	4.36	- -	35.52	- -
	16.99	21.40	10.13	4.29	4.46	25.83	58.66
	26.97	13.10	6.49	7.08	7.06	57.54	53.38
	27.01	12.70	6.35	7.08	7.06	54.94	51.58
	39.47	6.88	4.96	10.40	10.37	65.72	59.69
	39.75	5.93	4.61	10.38	10.40	50.64	53.27
	80.72	2.03	- -	21.09	- -	51.00	- -
	80.72	1.94	1.84	21.00	20.76	45.60	34.97
MIMP-OH2 50 LBS (2.5 LB)							
	8.76	55.20	- -	2.01	- -	9.20	- -
	8.81	57.80	9.11	2.05	2.17	10.41	18.75
	11.72	45.30	8.36	2.93	2.95	22.24	24.42
	11.99	- -	8.61	- -	3.03	- -	26.64
	16.95	27.80	8.10	4.36	4.39	39.17	39.68
	16.99	23.70	7.29	4.34	4.36	39.73	33.11
	26.97	12.90	5.71	7.07	7.00	56.10	42.98
	27.01	12.70	6.16	7.08	7.05	54.94	48.94
	39.47	6.66	4.55	10.38	10.32	61.85	51.62
	39.75	6.07	4.72	10.40	10.42	53.01	55.41
	80.69	2.26	2.71	21.25	21.25	65.86	65.32
	80.72	1.76	- -	20.78	- -	35.59	- -

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1MP-OH3 50 LBS (2.5 LB)							
	8.76	53.10	- -	1.98	- -	8.47	- -
	8.81	76.20	7.94	2.16	2.13	17.60	14.46
	11.72	50.40	8.67	2.97	2.96	26.45	26.12
	11.99	39.80	7.23	2.97	2.97	19.55	19.37
	16.97	- -	8.57	- -	4.41	- -	43.89
	16.99	25.50	7.85	4.37	4.39	34.53	37.70
	26.97	14.00	6.68	7.10	7.07	64.09	56.11
	27.01	13.10	6.49	7.09	7.07	57.82	53.50
	39.47	7.25	4.96	10.42	10.37	72.37	59.69
	39.75	6.60	4.44	10.45	10.38	62.23	50.10
	80.69	2.32	2.74	21.29	21.26	70.02	66.39
	80.72	2.04	2.54	21.10	21.19	51.62	58.65

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1SP-CH1 50 LBS (2.5 LB)							
	8.76	157.00	12.33	2.30	2.24	55.29	32.47
	8.81	127.00	18.45	2.28	2.32	40.69	67.10
	11.72	97.60	19.06	3.09	3.12	71.31	104.37
	11.99	136.00	20.01	3.20	3.20	123.32	117.00
	16.95	58.70	14.30	4.52	4.51	114.22	105.30
	16.99	68.50	- -	4.55	- -	142.07	- -
	26.97	13.60	8.78	7.09	7.16	61.16	88.71
	27.01	15.90	9.03	7.15	7.18	78.69	93.13
	39.47	8.38	6.45	10.49	10.48	93.62	92.00
	39.75	6.80	6.62	10.47	10.57	65.82	96.91
	80.69	2.72	3.79	21.47	21.51	100.36	111.16
	80.72	2.75	3.32	21.49	21.43	102.94	90.21

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
MISP-CH2 50 LBS (2.5 LB)							
	8.76	137.00	9.13	2.28	2.16	44.86	18.67
	8.81	156.00	25.48	2.31	2.35	55.80	118.31
	11.72	94.70	20.82	3.09	3.13	68.28	121.57
	11.99	139.00	18.30	3.20	3.19	127.22	100.32
	16.99	19.10	- -	7.18	- -	103.30	- -
	26.97	19.80	6.68	7.20	7.07	109.43	56.11
	27.01	- -	6.41	- -	7.06	- -	52.35
	39.47	8.22	5.57	10.48	10.42	90.54	72.25
	39.75	7.50	7.64	10.52	10.61	78.74	122.44
	80.72	2.76	3.95	21.48	21.54	103.64	119.00
	80.72	2.37	3.32	21.33	21.43	73.65	90.21

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1SP-CH3 50 LBS (2.5 LB)							
	8.76	209.00	10.46	2.32	2.20	85.34	24.03
	8.81	217.00	15.92	2.34	2.30	91.99	51.70
	11.72	- -	15.59	- -	3.10	- -	73.63
	11.99	95.00	19.21	3.17	3.19	73.88	109.07
	16.95	63.70	- -	4.53	- -	127.73	- -
	16.99	65.70	11.85	4.54	4.49	134.22	76.68
	26.97	19.30	7.87	7.18	7.13	104.90	73.88
	27.01	22.50	8.54	7.22	7.16	131.65	84.75
	39.47	- -	5.43	- -	10.41	- -	69.32
	39.75	6.86	6.26	10.48	10.55	66.90	88.47
	80.69	2.75	3.59	21.49	21.48	102.94	102.33
	80.72	- -	3.24	- -	21.41	- -	86.66

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	FQ-P (%)	FQ-I (%)
M1SP-CH4 50 LBS (2.5 LB)							
	8.76	186.00	12.95	2.31	2.25	71.53	35.47
	8.81	124.00	12.84	2.28	2.27	39.21	35.22
	11.72	143.00	16.75	3.13	3.11	123.32	83.41
	11.99	92.90	19.43	3.17	3.20	71.54	111.23
	16.99	15.20	--	7.12	--	73.02	--
	27.01	19.40	6.57	7.19	7.07	106.20	54.67
	39.47	7.42	5.71	10.43	10.43	75.48	75.22
	39.75	7.28	5.21	10.51	10.47	74.62	65.44
	80.69	3.42	3.26	21.63	21.41	163.48	87.79
	80.72	2.41	3.89	21.35	21.53	76.55	116.39

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ $(PSI-MS/LB^{1/3})$	LAMBDA-P $(FT/LB^{1/3})$	LAMBDA-I $(FT/LB^{1/3})$	EQ-P (%)	EQ-I (%)
MISP-CH5 25 LBS (1.25 LB)							
	8.76	98.40	8.25	2.89	2.75	59.01	21.73
	8.81	107.00	15.00	2.92	2.92	67.98	63.84
	11.72	79.20	12.52	3.93	3.89	111.23	69.17
	11.99	62.20	12.39	4.00	3.98	85.47	70.15
	16.95	34.10	- -	5.69	- -	112.27	- -
	16.99	23.90	8.85	5.64	5.63	68.05	64.49
	26.97	- -	6.52	- -	8.97	- -	75.22
	27.01	12.50	6.52	9.07	8.99	112.92	75.39
	39.47	6.79	4.35	13.29	13.09	134.18	67.46
	39.75	4.90	4.76	13.22	13.24	74.20	79.23
	80.69	2.54	4.05	27.27	27.26	178.26	174.51
	80.72	1.49	2.43	26.53	26.88	50.88	78.18

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ ($PSI\text{-}MS/LB^{1/3}$)	LAMBDA-P ($FT/LB^{1/3}$)	LAMBDA-I ($FT/LB^{1/3}$)	EQ-P (%)	EQ-I (%)
MISP-CH6 25 LBS (1.25 LB)							
	8.76	- -	7.45	- -	2.71	- -	17.97
	8.81	106.00	13.88	2.92	2.91	67.05	55.72
	11.72	59.00	11.29	3.90	3.87	73.71	57.91
	11.99	66.90	18.39	4.01	4.04	94.61	138.04
	16.99	28.60	- -	5.68	- -	88.32	- -
	16.99	28.40	9.54	6.72	5.65	145.55	73.35
	26.97	9.99	6.14	8.96	8.95	77.88	68.02
	27.01	11.40	7.25	9.04	9.03	97.41	89.87
	39.47	6.70	3.96	13.28	13.03	131.01	57.97
	39.75	4.88	4.80	13.22	13.25	73.60	80.17
	80.69	1.87	2.79	26.96	27.01	88.90	96.82
	80.72	1.50	2.56	26.55	26.94	51.76	84.81

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1SP-CH7 25 LBS (1.25 LB)							
	8.76	106.00	7.92	2.90	2.73	65.81	20.16
	8.81	85.50	16.02	2.89	2.93	48.87	71.56
	11.72	65.00	11.08	3.91	3.87	84.46	56.05
	11.99	77.60	14.06	4.03	4.00	116.23	87.19
	16.95	27.70	- -	5.65	- -	83.73	- -
	16.99	29.10	8.64	5.68	5.62	90.53	61.91
	26.97	- -	6.31	- -	8.96	- -	71.26
	27.01	11.00	6.83	9.03	9.01	91.89	81.48
	39.47	8.34	4.07	13.35	13.05	191.66	60.51
	39.75	7.12	4.35	13.40	13.19	149.24	68.21
	80.69	1.91	2.86	26.99	27.03	93.46	100.83
	80.72	- -	2.44	- -	26.89	- -	78.36

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ $(PSI\text{-}MS/LB^{1/3})$	LAMBDA-P $(FT/LB^{1/3})$	LAMBDA-I $(FT/LB^{1/3})$	FQ-P (%)	EQ-I (%)
M1SP-CH8 25 LBS (1.25 LB)							
	8.76	- -	7.85	- -	2.73	- -	19.82
	8.81	- -	15.11	- -	2.92	- -	64.62
	11.72	57.80	11.78	3.89	3.88	71.60	62.32
	11.99	42.10	13.54	3.94	4.00	48.95	81.71
	16.95	24.50	- -	5.63	- -	70.04	- -
	16.99	26.60	8.50	5.66	5.62	79.58	60.21
	26.97	8.48	6.80	8.91	8.99	58.51	80.61
	27.01	14.20	7.46	9.10	9.03	137.70	94.17
	39.47	5.46	4.24	13.19	13.08	89.62	64.82
	39.75	- -	4.63	- -	13.23	- -	75.49
	80.69	1.99	2.97	27.04	27.06	102.89	107.25
	80.72	1.79	2.45	26.90	26.89	80.18	78.71

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
MISP-CH9 12 LBS (.6 LB)							
	8.76	50.10	5.25	3.68	3.38	50.22	13.74
	8.81	- -	9.09	- -	3.66	- -	37.55
	11.72	18.50	7.37	4.81	4.88	29.73	39.32
	11.99	24.40	9.12	5.04	5.06	49.92	58.72
	16.95	15.30	5.82	7.21	7.09	76.51	45.09
	16.99	9.56	5.10	7.03	7.04	34.86	36.15
	26.97	6.14	4.74	11.46	11.42	72.39	63.72
	27.01	7.06	4.79	11.55	11.44	94.11	64.85
	39.47	3.88	2.99	16.90	16.62	99.75	53.04
	39.75	2.94	2.12	16.77	16.34	56.14	30.46
	80.69	1.13	2.06	34.05	34.45	56.75	87.39
	80.72	1.33	1.75	34.44	34.24	65.79	67.70

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ ($PSI-MS/LB^{1/3}$)	LAMBDA-P ($FT/LB^{1/3}$)	LAMBDA-I ($FT/LB^{1/3}$)	EQ-P (%)	EQ-I (%)
MISP-CH10 6 LBS (.6LB)							
	8.76	23.20	3.84	4.57	4.15	34.74	10.98
	8.81	28.50	6.10	4.66	4.51	48.64	26.00
	11.72	12.10	5.35	6.09	6.08	32.59	31.77
	11.99	14.40	7.45	6.33	6.38	47.46	57.93
	16.95	8.51	4.19	9.03	8.86	61.37	36.53
	16.99	7.99	- -	9.02	- -	55.20	- -
	26.97	4.09	3.14	14.42	14.23	68.62	45.85
	27.01	3.88	3.96	14.40	14.43	61.72	67.17
	39.47	2.29	- -	21.08	- -	66.10	- -
	39.47	1.93	1.91	20.95	20.62	44.77	36.44
	80.69	.85	1.22	42.93	42.86	58.17	55.09
	80.72	.70	1.09	42.07	42.60	34.57	46.21

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	FO-P (%)	FO-I (%)
M1MP-CH1 50 LBS (2.5 LB)							
	8.76	91.70	12.55	2.20	2.25	23.60	33.55
	8.81	102.00	12.11	2.24	2.25	28.83	[illegible]
	11.72	84.70	13.18	3.08	3.07	58.09	54.03
	11.99	91.20	14.52	3.16	3.16	69.67	67.17
	16.95	42.00	11.79	4.48	4.48	71.76	75.81
	16.99	37.60	12.12	4.47	4.5[illegible]	61.77	79.76
	26.97	15.40	7.35	7.13	7.10	74.52	65.81
	27.01	15.50	7.96	7.14	7.14	75.64	75.36
	39.47	6.72	5.27	10.38	10.40	62.90	65.66
	39.75	7.70	5.16	10.53	10.46	62.54	64.29
	80.69	1.75	2.85	20.76	21.30	35.02	70.73
	80.72	2.13	2.57	21.17	21.20	57.30	59.89
M1MP-CH2 50 LBS (2.5 LB)							
	6.76	137.00	7.34	2.28	[illegible]	[illegible]	12.32
	8.81	179.00	16.67	2.32	2.31	68.76	56.11
	11.72	86.60	11.75	3.08	3.05	59.99	44.96
	11.99	84.40	15.08	3.15	3.17	62.31	71.68
	16.95	36.20	- -	4.45	- -	58.02	- -
	16.99	43.60	- -	4.49	- -	76.22	- -
	26.97	10.60	7.96	6.98	7.13	40.10	75.19
	27.01	10.10	- -	6.97	- -	36.95	- -
	39.47	5.08	7.44	10.17	10.53	36.04	116.22
	39.75	5.52	- -	10.33	- -	43.88	- -
	80.69	2.20	- -	21.22	- -	61.81	- -
	80.72	2.33	2.41	21.31	21.13	70.81	53.08

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	FO-P (%)	FO-I (%)
M1MP-CH3 50 LBS (2.5 LB)							
	8.76	97.10	8.22	2.21	2.13	25.94	15.33
	8.81	87.40	12.05	2.20	2.25	22.26	31.42
	11.72	91.50	10.69	3.09	3.03	64.97	38.03
	11.99	93.10	14.27	3.17	3.16	71.76	65.18
	16.95	35.50	- -	4.44	- -	56.40	- -
	16.99	47.10	8.46	4.50	4.41	84.92	42.99
	26.97	12.80	6.77	7.07	7.07	55.39	57.29
	27.01	14.10	6.62	7.11	7.09	65.14	58.21
	39.47	5.64	3.68	10.26	10.17	44.74	36.28
	39.75	5.93	4.66	10.38	10.41	50.64	54.34
	80.69	- -	2.58	- -	21.20	- -	60.17
	80.72	2.27	2.56	21.27	21.20	66.63	59.58

TEST DATA

R	P	I
(FT)	(PSIG)	(PSI-MS)

MIMP=1R 55 LBS (1.5 LB) CYLINDER L/D = 1.7

8.80	353.00	107.00
8.81	268.00	106.00
11.77	165.00	81.70
11.97	175.00	91.30
16.97	51.20	41.40
16.98	61.50	46.70
26.98	20.00	33.60
27.02	13.50	25.70
39.53	5.76	20.90
39.67	7.29	19.60
80.65	2.13	11.10
80.72	2.00	10.60

MIMP=2R 55 LBS (1.5 LB) CYLINDER L/D = 1.7

8.80	359.00	127.00
8.81	236.00	98.00
11.77	111.00	- -
11.97	176.00	90.80
16.97	68.90	49.70
16.98	68.10	40.90
26.98	13.00	23.60
27.02	18.30	28.70
39.53	6.14	22.10
39.67	6.60	20.90
80.65	2.07	10.40
80.72	2.12	11.00

MIMP=3R 35 LBS (400GM) CYLINDER L/D = 1.7

8.80	307.00	69.30
8.81	75.30	44.30
11.77	44.70	22.10
11.97	44.10	47.10
16.97	19.50	25.90
16.98	19.90	20.40
26.98	9.34	17.90
27.02	9.01	15.00
39.53	3.35	10.50
39.67	3.95	10.20
80.65	1.31	5.26
80.72	1.30	5.33

TEST DATA

R	P	I
(FT)	(PSIG)	(PSI-MS)
M1SP-4R 35 LBS (400GM) CYLINDER L/D = 1.7		
8.80	66.30	55.50
8.81	143.00	48.20
11.77	38.30	30.60
11.97	57.90	43.90
16.97	22.60	24.70
16.98	16.40	20.20
26.98	7.84	17.60
27.02	9.54	15.40
39.55	4.76	10.80
39.67	2.70	10.70
80.65	1.49	5.22
80.72	1.13	5.28
M1SP-1R 43 LBS (1.5 LB) CYLINDER L/D = 1.7		
8.80	421.00	132.00
8.81	325.00	112.00
11.77	138.00	64.00
16.97	69.70	46.20
16.98	64.40	38.00
26.98	18.10	30.50
27.02	15.50	27.30
39.53	6.96	19.50
39.67	6.99	19.30
80.65	1.99	10.20
80.72	2.00	10.30
M1SP-2R 43 LBS (1.5 LB) CYLINDER L/D = 1.7		
8.80	271.00	120.00
8.81	411.00	119.00
11.77	186.00	51.10
11.97	126.00	77.90
16.97	35.60	43.30
16.98	68.90	36.90
26.98	18.30	30.50
27.02	14.60	26.70
39.53	7.66	20.70
39.67	6.04	19.50
80.65	2.28	10.00
80.72	1.83	9.99

TEST DATA

M1SP=3R 27 LBS (400GM) CYLINDER L/D = 1.7

R (FT)	P (PSIG)	I (PSI-MS)
8.80	338.00	163.00
8.81	221.00	79.90
11.77	78.20	50.00
11.97	128.00	38.70
16.97	31.70	27.60
16.98	19.90	22.50
26.98	12.80	21.60
27.02	11.10	18.30
39.53	3.90	13.70
39.67	4.99	11.50
80.65	1.41	6.51
80.72	1.48	6.42

M1SP=4R 27 LBS (400GM) CYLINDER L/D = 1.7

R (FT)	P (PSIG)	I (PSI-MS)
8.80	293.00	106.00
8.81	151.00	77.90
11.77	59.70	39.00
11.97	119.00	59.30
16.97	29.30	30.40
16.98	32.30	22.60
26.98	10.30	20.90
27.02	9.58	18.30
39.53	3.98	13.70
39.67	4.21	12.10
80.65	1.48	6.25
80.72	1.49	6.63

TEST DATA

R	P	T
(FT)	(PSIG)	(PSI-MS)
MISP-OH1 50 LBS (2.5 LB)		
8.76	84.70	- -
8.76	103.00	84.40
11.72	- -	33.00
11.99	59.60	45.70
16.95	39.10	35.70
16.99	- -	32.10
26.97	18.60	28.80
27.01	15.70	26.50
39.47	7.92	21.00
39.75	6.61	19.50
56.92	4.59	- -
57.06	3.52	15.10
MISP-OH2 50 LBS (2.5 LB)		
8.76	- -	28.10
8.81	90.70	44.50
11.72	53.70	33.10
11.99	58.30	42.10
16.95	32.20	33.60
16.99	30.20	36.80
26.97	11.50	- -
27.01	14.20	24.00
39.47	7.71	20.80
39.75	6.77	21.40
80.69	2.02	9.30
80.72	1.94	9.66
MISP-OH3 50 LBS (2.5 LB)		
8.76	94.90	29.40
8.81	- -	42.00
11.72	- -	33.30
11.99	59.50	39.40
16.95	34.80	36.40
16.99	- -	34.00
26.97	4.84	28.40
27.01	14.80	26.20
39.47	7.45	19.80
39.75	7.21	20.30
80.69	- -	12.80
80.72	1.91	9.20

TEST DATA

R	P	I
(FT)	(PSIG)	(PSI-MS)
M1MP-OH1 50 LBS (2.5 LB)		
8.76	- -	41.20
8.81	78.50	41.50
11.72	50.50	42.90
11.99	71.60	- -
16.95	26.10	- -
16.99	21.40	38.60
26.97	13.10	24.80
27.01	12.70	24.30
39.47	6.88	18.90
39.75	5.93	17.60
80.72	2.03	- -
80.72	1.94	7.17
M1MP-OH2 50 LBS (2.5 LB)		
8.76	55.20	- -
8.81	57.80	36.90
11.72	45.30	33.20
11.99	- -	34.00
16.95	27.80	31.30
16.99	23.70	28.40
26.97	12.90	22.00
27.01	12.70	23.60
39.47	6.66	17.40
39.75	6.07	18.00
80.69	2.26	10.30
80.72	1.76	- -
M1MP-OH3 50 LBS (2.5 LB)		
8.76	53.10	- -
8.81	76.20	32.90
11.72	50.40	34.30
11.99	39.80	29.20
16.97	- -	33.00
16.99	25.50	30.40
26.97	14.00	25.50
27.01	13.10	24.80
39.47	7.25	18.90
39.75	6.60	17.00
80.69	2.32	10.40
80.72	2.04	9.66

TEST DATA

R	P	I
(FT)	(PSIG)	(PSI-MS)

M1SP-CH1 50 LBS (2.5 LB)

6.76	157.00	48.10
8.81	127.00	70.00
11.72	97.60	71.60
11.99	136.00	75.00
16.95	58.70	53.70
16.99	68.50	- -
26.97	13.60	33.10
27.01	15.90	34.00
39.47	8.38	24.30
39.75	6.80	24.90
80.69	2.72	14.20
80.72	2.75	12.50

M1SP-CH2 50 LBS (2.5 LB)

8.76	137.00	37.00
8.81	156.00	95.50
11.72	94.70	78.00
11.99	139.00	68.80
16.99	19.10	65.00
26.97	19.80	25.50
27.01	- -	24.50
39.47	8.22	21.10
39.75	7.50	28.60
80.72	2.76	14.80
80.72	2.37	12.50

M1SP-CH3 50 LBS (2.5 LB)

8.76	209.00	41.60
8.81	217.00	60.90
11.72	- -	59.00
11.99	95.00	72.10
16.95	63.70	- -
16.99	65.70	44.80
26.97	19.30	29.80
27.01	22.50	32.20
39.47	- -	20.60
39.75	6.86	23.60
80.69	2.75	13.50
80.72	- -	12.20

TEST DATA

R (FT)	P (PSIG)	I (PSI-MS)

M1SP-CH4 50 LBS (2.5 LB)

8.76	186.00	50.30
8.81	124.00	49.90
11.72	143.00	63.20
11.99	92.90	72.90
16.99	15.20	40.00
27.01	19.40	25.10
39.47	7.42	21.60
39.75	7.28	19.80
80.69	3.42	12.30
80.72	2.41	14.60

M1SP-CH5 25 LBS (1.25 LB)

8.76	98.40	26.30
8.81	107.00	45.30
11.72	79.20	37.70
11.99	62.20	37.30
16.95	34.10	- -
16.99	23.90	26.70
26.97	- -	19.60
27.01	12.50	19.60
39.47	6.79	13.10
39.75	4.90	14.30
80.69	2.54	12.00
80.72	1.49	7.31

M1SP-CH6 25 LBS (1.25 LB)

8.76	- -	24.10
8.81	106.00	42.10
11.72	59.00	34.20
11.99	66.90	54.60
16.99	28.60	- -
16.99	28.40	28.70
26.97	9.99	18.50
27.01	11.40	21.70
39.47	6.70	12.00
39.75	4.88	14.40
80.69	1.87	8.33
80.72	1.50	7.68

TEST DATA

R (FT)	P (PSIG)	I (PSI-MS)
M1SP-CH7 25 LBS (1.25 LB)		
8.76	106.00	25.40
8.81	85.50	48.20
11.72	65.00	33.60
11.99	77.60	42.10
16.95	27.70	- -
16.99	29.10	26.10
26.97	- -	19.00
27.01	11.00	20.50
39.47	8.34	12.30
39.75	7.12	13.10
80.69	1.91	8.54
80.72	- -	7.32
M1SP-CH8 25 LBS (1.25 LB)		
8.76	- -	25.20
8.81	- -	45.60
11.72	57.80	35.60
11.99	42.10	40.60
16.95	24.50	- -
16.99	26.60	25.70
26.97	8.48	20.40
27.01	14.20	22.30
39.47	5.46	12.80
39.75	- -	13.90
80.69	1.99	8.87
80.72	1.79	7.34
M1SP-CH9 12 LBS (.6 LB)		
8.76	50.10	13.60
8.81	- -	21.90
11.72	18.50	17.70
11.99	24.40	21.60
16.95	15.30	13.90
16.99	9.56	12.30
26.97	6.14	11.20
27.01	7.06	11.30
39.47	3.88	7.10
39.75	2.94	5.16
80.69	1.13	4.82
80.72	1.33	4.12

TEST DATA

R (FT)	P (PSIG)	I (PSI-MS)
M1SP-CH10 6 LBS (.6LB)		
8.76	23.20	8.10
8.81	28.50	11.90
11.72	12.10	10.30
11.99	14.40	14.00
16.95	8.51	8.02
16.99	7.99	- -
26.97	4.09	5.96
27.01	3.88	7.42
39.47	2.29	- -
39.47	1.93	3.65
80.69	.85	2.29
80.72	.70	2.06
M1MP-CH1 50 LBS (2.5 LB)		
8.76	91.70	48.90
8.81	102.00	47.30
11.72	84.70	50.30
11.99	91.20	55.10
16.95	42.00	44.60
16.99	37.60	45.80
26.97	15.40	27.90
27.01	15.50	30.10
39.47	6.72	20.00
39.75	7.70	19.60
80.69	1.75	10.80
80.72	2.13	9.78
M1MP-CH2 50 LBS (2.5 LB)		
8.76	137.00	30.90
8.81	179.00	63.60
11.72	86.60	45.20
11.99	84.40	57.10
16.95	36.20	- -
16.99	43.60	- -
26.97	10.60	30.10
27.01	10.10	- -
39.47	5.08	27.90
39.75	5.52	- -
80.69	2.20	- -
80.72	2.33	9.20

TEST DATA

R (FT)	P (PSIG)	I (PSI-MS)
MIMP-CH3 50 LBS (2.5 LB)		
8.76	97.10	33.90
8.81	87.40	47.10
11.72	91.50	41.40
11.99	93.10	54.20
16.95	35.50	- -
16.99	47.10	32.60
26.97	12.80	25.80
27.01	14.10	26.00
39.47	5.64	14.30
39.75	5.93	17.80
80.69	- -	9.81
80.72	2.27	9.75

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ ($PSI-MS/LB^{1/3}$)	LAMBDA-P ($FT/LB^{1/3}$)	LAMBDA-I ($FT/LB^{1/3}$)	FO-P (%)	FO-I (%)
M1SP-OH 50 LBS CURVE FIT							
	2.00	98.00	12.80	2.00	2.00	19.37	29.72
	2.00	- -	6.60	- -	2.00	- -	9.80
	3.00	58.00	10.80	3.00	3.00	32.88	38.23
	3.00	- -	8.40	- -	3.00	- -	25.20
	5.00	26.50	8.50	5.00	5.00	54.55	51.38
	7.00	15.00	7.00	7.00	7.00	67.95	59.61
	9.00	3.60	5.90	9.00	9.00	13.03	64.36
	18.00	2.70	3.05	18.00	18.00	58.26	61.45
	22.50	1.76	2.20	22.50	22.50	45.18	51.53
M1SP-CH 50 LBS CURVE FIT							
	2.25	208.00	12.50	2.25	2.25	77.05	33.34
	3.00	143.00	20.00	3.00	3.00	108.65	107.49
	5.00	47.50	11.30	5.00	5.00	117.43	61.94
	7.00	20.00	8.00	7.00	7.00	102.08	73.95
	9.00	10.05	6.40	9.00	9.00	79.09	73.29
	18.00	3.18	3.90	18.00	18.00	81.45	89.98
	22.50	2.48	3.45	22.50	22.50	95.22	102.85

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ (PSI-MS/LB$^{1/3}$)	LAMBDA-P (FT/LB$^{1/3}$)	LAMBDA-I (FT/LB$^{1/3}$)	EQ-P (%)	EQ-I (%)
M1MP-OH 50 LBS CURVE FIT							
	2.00	56.00	9.50	2.00	2.00	9.31	18.00
	2.00	- -	6.80	- -	2.00	- -	10.30
	3.00	43.50	8.70	3.00	3.00	22.62	26.70
	3.00	- -	7.80	- -	3.00	- -	22.29
	5.00	21.30	7.30	5.00	5.00	40.57	40.09
	7.00	12.30	6.20	7.00	7.00	50.72	49.03
	9.00	8.20	5.25	9.00	9.00	57.13	53.43
	18.00	2.79	3.05	18.00	18.00	62.36	61.45
	22.50	2.00	2.50	22.50	22.50	59.94	62.66
M1MP-CH 50 LBS CURVE FIT							
	2.25	94.00	12.00	2.25	2.25	26.09	31.13
	3.00	93.00	14.20	3.00	3.00	60.99	60.39
	5.00	30.00	10.05	5.00	5.00	64.36	67.59
	7.00	14.00	7.50	7.00	7.00	61.46	66.63
	9.00	8.30	5.80	9.00	9.00	58.27	62.63
	18.00	2.78	3.08	18.00	16.00	61.90	62.39
	22.50	2.10	2.55	22.50	22.50	66.67	64.60

SUMMARY OF EXPERIMENTAL RESULTS

NORTH AND EAST BLAST LINES

BASED ON INDIVIDUAL DATA POINTS

TEST TYPE	R (FT)	P (PSI)	$I/W^{1/3}$ ($PSI-MS/LB^{1/3}$)	LAMBDA-P ($FT/LB^{1/3}$)	LAMBDA-I ($FT/LB^{1/3}$)	FQ-P (%)	FQ-I (%)
M1SP 43 + 27 LBS CYLINDER CURVE FIT							
	2.50	400.00	35.00	2.50	2.50	274.01	220.91
	3.00	237.00	24.00	3.00	3.00	219.78	146.42
	5.00	47.50	11.60	5.00	5.00	117.43	85.54
	7.00	18.20	8.30	7.00	7.00	89.51	78.49
	9.00	10.03	6.80	9.00	9.00	78.85	80.75
	18.00	2.92	3.45	18.00	18.00	68.49	74.38
	25.00	1.68	2.30	25.00	25.00	55.85	64.40
M1MP 55 LBS CYLINDER CURVE FIT							
	2.25	285.00	28.00	2.25	2.25	120.93	131.47
	3.00	177.00	20.00	3.00	3.00	145.72	107.49
	5.00	31.00	10.02	5.00	5.00	67.21	67.26
	7.00	14.80	7.60	7.00	7.00	66.64	68.07
	9.00	8.00	6.10	9.00	9.00	54.87	67.88
	18.00	2.50	3.20	18.00	18.00	49.59	66.19
	22.50	1.97	2.55	22.50	22.50	57.98	64.60

APPENDIX B

TNT EQUIVALENCY CALCULATION PROCEDURE

Computational Procedure

The computational procedure used to obtain TNT equivalencies is illustrated in this appendix. TNT equivalency for pressure is defined as the ratio of charge weight (i.e., TNT weight/test explosive weight) that will give the same peak pressure at the same radial distance from each charge. Similarly, the TNT equivalency for impulse is defined as the ratio of charge weights that will give the same positive impulse at the same radial distances. Since the booster used to detonate the test explosive, propellant, or pyrotechnic may be of the order of 10 percent of the test material weight it is necessary to account for its contribution to the explosive output (i.e., peak pressure and impulse).

The symbols used in this discussion are:

W	Weight, lb
R	Radial distance from charge, ft
$\lambda=R/W^{1/3}$	Scaled distance, ft/lb$^{1/3}$
P	Peak overpressure, psig
I	Positive impulse, psi-msec
E	TNT equivalency, percent

These subscripts and superscripts are self-explanatory when applied to the above symbols:

S	Test sample
B	Booster
TNT	TNT explosive
I	Impulse
P	Pressure
*	Quantity is not adjusted for booster weight
TOT	Total charge weight, booster plus sample

Pressure equivalency is determined by first measuring the quantities W_S, R, and P_{SB}. Where P_{SB} is the peak pressure measured when the sample was detonated with a C4 booster, it includes an energy contribution from both C4 and sample.

One must first approximate an equivalent booster weight, in terms of the charge sample weight, so that its weight can be included in the total charge weight. The approximation is found by obtaining λ_{TNT}, from Figure B1, for $P_{SB} = P_{TNT}$.

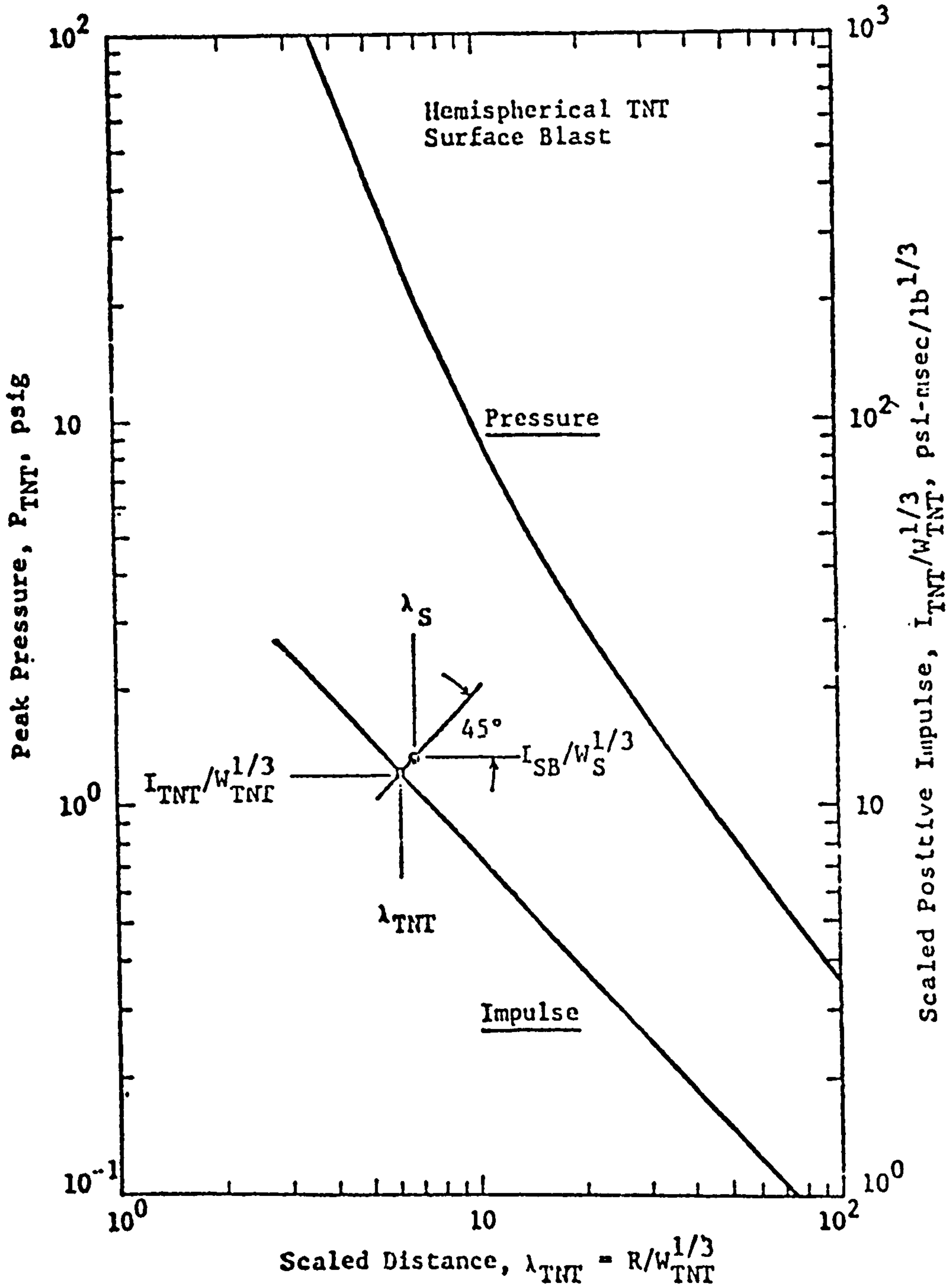


Fig B1 TNT pressure and impulse

The first approximation for TNT pressure equivalency is then:

$$E_P^* - W_{TNT}/W_S = (\lambda_S/\lambda_{TNT})^3$$

where

$$\lambda_S = R/W_S^{1/3}$$

and

$$\lambda_{TNT} = R/W_{TNT}^{1/3}$$

Since the pressures are to be equal at the same radial distance, the R's cancel in the above equation. One applies this approximated equivalency, E_P^*, to the weight of the booster to obtain the total charge weight

$$W_{TOT} = W_S + (1/E_P^*)\ W_B(1.25)$$

A factor of 1.25 is applied to the C4 booster weight to obtain its equivalent TNT weight.

A new λ is now computed from

$$\lambda_{TOT} = R/W_{TOT}^{1/3}$$

and a corrected pressure TNT equivalency is computed.

$$E_P = W_{TNT}/W_{TOT} = (\lambda_{TOT}/\lambda_{TNT})^3$$

The P subscript indicates a scale distance for pressure and is computed from the revised sample weight. This iterative process can be repeated using the revised value of E_P to recompute the weight of the booster in terms of the sample weight, etc. However, the second iteration has a small effect on equivalency.

Impulse equivalency is determined first by measuring W_S, R, and I_{SB}, where I_{SB} is the impulse measured when the sample charge was detonated with a C4 booster. One must first approximate an equivalent booster weight, in terms of the charge sample weight. The approximation is found by locating the data point $I_{SB}/W_B^{1/3}$: λ_S on Figure B1. A 45-degree line is drawn through this data point to intersect with the TNT impulse curve. Values of λ_{TNT} and $I_{TNT}/W_{TNT}^{1/3}$

are read at the intersection of the two straight lines. These values give the equivalent TNT weight for equal impulses and radial distances.

At the data point $I_{SB}/W_S{}^{1/3}$ and λ_S let

$$a_S = I_{SB}/W_S{}^{1/3} \text{ or } I_{SB} = a_S W_S{}^{1/3}$$

and

$$\lambda_S = R/W_S{}^{1/3} \text{ or } R = \lambda_S W_S{}^{1/3}.$$

For equal impulses

$$I_{SB} = I_{TNT}$$

or

$$a_S W_S{}^{1/3} = a_{TNT} W_{TNT}{}^{1/3}$$

and for equal radial distances

$$\lambda_S W_S{}^{1/3} = \lambda_{TNT} W_{TNT}{}^{1/3}$$

Divide these two equations and get

$$\frac{a_S}{a_{TNT}} = \frac{S}{TNT}$$

Take the log of the above equation

$$\log a_S - \log a_{TNT} = \log \lambda_S - \log \lambda_{TNT}.$$

This equation shows that a 45-degree construction line on a log-log plot will intersect the impulse curve and data point in such a way as to satisfy the conditions of equal positive impulses at the same radial distance.

The first approximation for TNT impulse equivalency is

$$E_I^* = W_{TNT}/W_S$$

$$E_I^* = (I_{SB}/W_S^{1/3})^3/(I_{TNT}/W_{TNT}^{1/3})^3 = \frac{1/W_S}{1/W_{TNT}}$$

Since $I_{SB} = I_{TNT}$ they cancel in the above equation.

One applies this approximated equivalency, E_I^*, to the weight of the booster to obtain the total charge weight

$$W_{TOT} = W_S + (1/E_I^*) W_B (1.25).$$

A new scaled distance

$$\lambda_{TOT} = R/W_{TOT}^{1/3}$$

and scaled impulse is then computed as

$$I_{SB}/W_{TOT}^{1/3}$$

This data point is now located on Figure B1 and new $I_{TNT}/W_{TNT}^{1/3}$ and λ_{TNT} values are determined from the 45-degree line intersection method described.

The correct impulse equivalency then becomes

$$E_I = W_{TNT}/W_{TOT}$$

$$E_I = (I_{SB}/W_{TOT}^{1/3})^3/(I_{TNT}/W_{TNT}^{1/3})^3.$$

Computerized Calculations

The TNT equivalencies of the explosive material are determined by use of a computer program. The first step in the program is to fit a curve to the test data utilizing a manual curve fit method. That is, a curve is drawn through the data points that are most representative of the characteristic trend. To do this, the pressures with their corresponding gage distances (and, similarly, impulses with their distances) are entered into the program as input data. Scaled distances are then obtained by dividing the gage distances by the cube root of the charge weight. Where the input consists of experimental data from more than one test conducted under identical conditions, the pressure and impulse values are averaged before the curve fit is performed. Impulse input is converted to scaled impulse by dividing by the cube root of the charge weight. This is performed before averaging or curve fitting is done. Polynomial fits of the first and second order were attempted; however, inadequate results were obtained.

Having chosen the curve which best describes the test data, pressure and impulse values with their corresponding gage distances are entered into the program along with the appropriate curve coefficient. The TNT equivalence is determined twice, once using points from the fitted curve at scaled distances corresponding to the gage locations, and once using the actual data point. This is done for both pressure and impulse data.

In the program, the TNT pressure and impulse curves versus scaled distance appear as polynomial expressions. To determine the pressure equivalency, the TNT scaled distance at a pressure equal to the test pressure is determined from this equation. The TNT equivalency at each pressure data point is computed as the curve of the ratio of the scaled distance of the test data to the TNT scaled distance.

A correction is made to the equivalency calculation to include the weight of the booster in the total weight. The TNT equivalency is then recomputed on the basis of the corrected weight. This is an iterative process and continued until the change in the ratio of the scaled distance to the TNT scaled distance is negligible.

A similar procedure is followed for impulse data. Since scaled impulse is used rather than actual impulse, a correction in the total weight of the explosive to account for the booster weight involved making corrections to the scaled impulse as well as the scaled distance.

The computer output for the pressure tests includes, for the averaged and curve fitted data, scaled distance, corrected scaled distance, pressure, total weight, and TNT equivalency at each gage location. Output based on raw data includes scaled distance, corrected scaled distance, input pressure, TNT equivalency, and gage distance at each data point. The output for the impulse tests is similar except that scaled impulse and corrected impulse are included.

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